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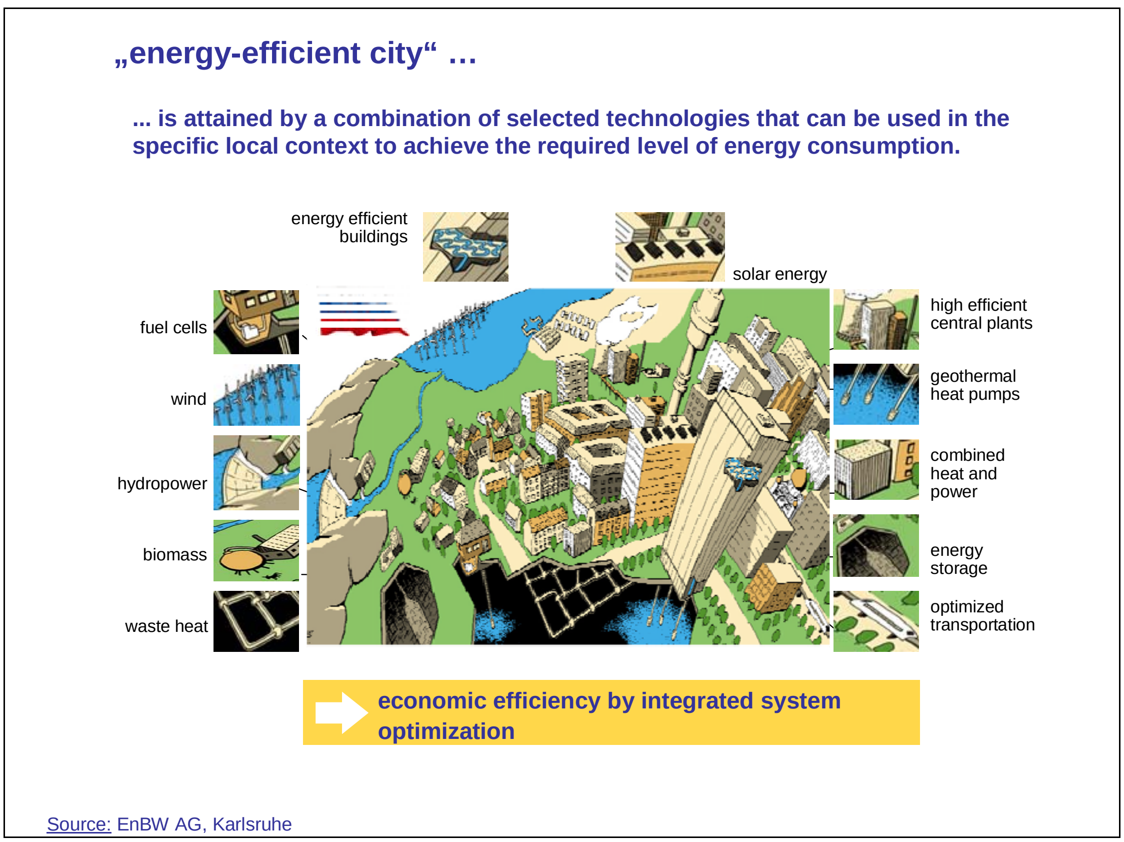
Proceedings of the ERDC-CERL Net Zero Energy (NZE) Installation and Deployed Bases Workshop

Colorado Springs, CO, 3 – 4 February 2009

Carl A. Feickert, Thomas J. Hartranft, Franklin H. Holcomb,
John L. Vavrin, Alexander M. Zhivov, and Hyunjoo Kim

June 2009



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Construction Engineering Research Laboratory
U.S. Army Engineer Research and Development Center
2902 Newmark Drive
Champaign, IL 61822

Hyunjoo Kim

The PERTAN Group
Champaign, IL 61820

Final report

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Abstract. The United States faces profound security and economic challenges directly related to the growing constraints on established global energy resources. U.S. Army energy demand is projected to outgrow affordable supplies even after accounting for the impact of anticipated energy efficiency and management innovations. In order to prevent unacceptable energy scarcities and unaffordable costs, the Army needs a paradigm-changing approach that combines the concept of net zero energy (NZE) usage with a comprehensive and integrated architecture encompassing energy generation, delivery, storage, and demand management. The purpose of that change would be to facilitate development of a suite of ultra-low-energy solutions that would approach NZE usage by enabling real-time optimization of power supply, demand, and storage management for Army facilities, emplacements, or fixed installations of any size.

In support of these objectives, the U.S. Army Engineer Research and Development Center – Construction Engineering Research Laboratory (ERDC-CERL) convened a workshop to provide a forum for leading research scientists and engineers to help the Army define the technology requirements for implementing this vision. This report summarizes the proceedings of the workshop and defines a way forward for an applied research program capable of producing ultra-low-energy solutions for the widest variety of military facilities and emplacements.

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Executive Summary

As established global energy resources become increasingly constrained, the United States faces profound new security and economic challenges directly arising from those developments. Energy consumption by both the military and non-military sectors is expected to continue increasing, even after accounting for the introduction of new, energy-efficient technologies. Consequently, a paradigm-changing approach to energy production, delivery, storage, and demand management is needed in order to prevent unacceptable scarcities and unaffordable costs. For the U.S. Army, such a new approach would combine the concept of net zero energy (NZE) usage with a comprehensive and integrated architecture that encompasses energy generation, delivery, storage, and demand management.

The practical objective of any Army paradigm shift within the energy domain should be a fieldable suite of ultra-low-energy solutions that can be optimized to support logistics and operations for any size or type of military facility. This suite of solutions must be readily adaptable to a wide variety of military mission requirements, facility characteristics, locations, and climates. It must provide garrison commanders the ability to continually maintain the optimal balance of affordability, energy security, energy footprint, and occupant well-being depending on changing mission requirements, threat levels, utility market prices, etc.

A successfully designed and developed suite of ultra-low-energy solutions would consist of an adaptable, modular, scalable power and thermal energy architecture able to accommodate any type of localized mission need, facility size, location, and climate. Constituent technologies would at minimum include facility automation, utility management and control systems, and power delivery systems fully integrated with onsite generation, storage, and conservation capabilities. Such a suite of technologies should be capable of optimizing energy operations and consumption on a day-to-day — and even an hour-by-hour — basis. The scope of this extensive challenge is obvious considering the huge diversity of military facilities and their vastly differing energy requirements. Army facilities may range from a lecture hall, on the low end of consumption, to energy-intensive command-and-control complexes, maintenance shops, and research installa-

tions with very high computer, environmental conditioning, or industrial process plug loads.

In order to facilitate development of this suite of ultra-low-energy solutions, a comprehensive and integrated architecture that encompasses power generation, delivery, storage, and demand management must be identified or developed. In support of that requirement, the U.S. Army Engineer Research and Development Center – Construction Engineering Research Laboratory (ERDC-CERL) convened a workshop to provide a forum for leading energy scientists and engineers to help the Army define the technology requirements for implementing this vision. Individual workshop sessions were conducted on the following topics:

- renewable energy
- thermal and electrical energy storage
- power and energy architecture
- physical architecture
- energy conservation
- building envelope and material sciences
- tool and system analysis methodologies.

This report summarizes these individual deliberations and defines a way forward for an applied research program capable of producing ultra-low-energy solutions for the widest variety of military facilities and emplacements. The goals of each session were to provide workshop participants with a better understanding of:

- the state of technology maturity
- technical barriers to the next generation of solutions
- prospective applied research projects to overcome technical barriers
- opportunities to network multiple categories of technology into an advanced suite of ultra-low-energy tools and methodologies for military facility and logistical operations.

The invited presenters and participating Army stakeholders produced a draft consensus technology roadmap to help inform future Army energy research and development investment decisions. The development and implementation of this new energy production and management paradigm would have potential applications and beneficial sustainability implications extending far beyond the military sector.

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Preface

The Net Zero Energy (NZE) Installation and Deployed Bases Two-Day Workshop, convened 3–4 February 2009 at Colorado Springs, CO, was sponsored by the U.S. Army Engineer Research and Development Center – Construction Engineering Research Laboratory (ERDC-CERL) with funding provided by the U.S. Army Tank, Automotive, Research, Development and Engineering Center (TARDEC). Publication of the workshop proceedings was funded by ERDC-CERL under P2 Project 142806, "Support of Collaborative Energy Research." The ERDC-CERL technical monitor was Dr. Thomas Hartranft, CEERD-CF-E.

This report was prepared by the Energy Branch (CF-E) of the Facilities Division (CF), ERDC-CERL. A portion of the work associated with workshop organization and documentation was performed under contract by The PERTAN Group, Champaign, IL. At the time of publication, Franklin H. Holcomb was Acting Chief, CEERD-CF-E; L. Michael Golish was Chief, CEERD-CF; and Martin J. Savoie was the Technical Director for Installations. The Deputy Director of ERDC-CERL was Dr. Kirankumar Topudurti and the Director was Dr. Ilker Adiguzel.

The following individuals served as workshop session chairs:

- Dr. Reinhard Jank, International Energy Agency and manager for the Freiburg, Germany, NZE plan (Keynote Presentation, "Energy-Efficient Community Systems")
- Dr. Andy Walker, National Renewable Energy Laboratory (Renewables for NZE)
- Dan Rastler, Electric Power Research Institute (Thermal and Electrical Energy Storage for NZE)
- Dr. Bob Lassiter, University of Wisconsin – Madison (Power and Energy Architecture for NZE)
- Dr. Thomas Hartranft, ERDC-CERL (Physical Architecture for NZE)
- Dr. Alexander Zhivov, ERDC-CERL (Energy Conservation for NZE)
- Bill Rose, University of Illinois at Urbana-Champaign (Building Envelope and Materials Technology for NZE)
- Dr. Jacob Brouwer, University of California – Irvine (Tools and Systems Analyses Methodologies for NZE).

The following individuals are gratefully acknowledged for their contributions to the success of the workshop:

- William Brown III, ERDC-CERL; and Gonzalo Perez and Sharie Carter-Bane, The PERTAN Group, for their considerable efforts in organizing, facilitating, and hosting the workshop.
- Michael Bordenaro, an independent subcontractor to The PERTAN Group, for serving as a recorder for the workshop sessions.

COL Gary E. Johnston was the Commander and Executive Director of ERDC, and Dr. James R. Houston was the Director.

1 Introduction

1.1 Problem statement

Army installations are essential for the development and sustainment of operational capabilities and readiness to serve and protect the nation and its interests. Installations are small cities with a full spectrum of facility types and utility requirements that use large amounts of energy. The prime movers for Installation energy requirements have historically been thermal (steam) and most particularly electrical in nature. And in an increasingly energy constrained world, the Army and its logistic support envisions a future where its energy needs are designed and fulfilled by an elegant suite of ultra-low-energy solution options that can be tailored for adaptation at any Army installation or forward-operating base (FOB), depending on climatic zone, mission needs, etc. Furthermore, U.S. domestic and military energy policy is directly linked to the size and growth rate of the U.S. Gross Domestic Product (GDP) and geopolitical considerations of fossil energy usage and greenhouse gas challenges. Until recently, advances in energy efficiency and conservation have enabled the United States' cost of energy, as a fraction of GDP, to remain stable at about 2.5% over the past 10 years (Lin 2007). However, in a recent review of the role of energy security and independence for military installations, Hartranft (2007) found it is expected that both domestic and military energy consumption will continue to increase even as more energy-efficient applications are developed. The inescapable conclusion is that energy resource limitations are a non-negotiable constraint for the foreseeable future. This constraint is particularly significant for fixed military installations and warfighting activities as the military services adopt energy-intensive technologies such as directed-energy weapons and supporting equipment now being envisioned for next-generation capabilities.

The Army is now in a position to collect enormous economic and sustainability benefits by revising its traditional energy usage assumptions with respect to all global sources, and by redefining energy conservation to include innovative modes not currently used. In this new paradigm, so-called "secondary" sources of energy — solar, photovoltaic, wind, biofuels, organic compound remediation — are to be placed on a competitive footing with prime power sources such as standby diesel generators, electrical utilities, and traditional steam generation plants. The conservation side of

the equation requires one to begin seriously tracking the flow of all free energy and its storage within the “installation envelope,” so as to approach realistic thermodynamic constraints for all rejected energy. To accomplish these ends will be neither straightforward nor inexpensive. Federal energy policy does exist to support such a vision (Energy Policy Act of 2005, Pub.L. 109-58), but presently there does not exist an overarching power delivery, energy storage-demand architecture and methodology to accomplish this. The Army’s present and future energy requirements are a combination of ultra-low- and high-energy-intensity facilities with mission constraints requiring the tailoring and optimization of energy security, affordability, environmental footprint, occupant well-being, as appropriate depending on the threat condition, mission needs, and utility market prices.

To address these issues requires the development of a properly designed and executed suite of ultra-low-energy systems that would enable adaptable, modular, scalable building-block power and thermal energy architecture so as to accommodate a full spectrum of local mission needs, from a few clustered facilities, an installation subsection, a full installation or deployed base. Accommodating this variability in an ultra-low-energy environment will require a highly integrated combination of building automation, utility management and control systems, and power delivery systems with the capability to offer integration of onsite power, energy storage, and energy conservation. The central features of an integrated suite of technologies, control methodologies, and analysis tools must not only optimize overall system design but also day-to-day — and even hour-by-hour — operation.

The U.S. Army Engineer Research and Development Center – Construction Engineering Research Laboratory (ERDC-CERL) and the Research, Development, and Engineering Command (RDECOM) are investigating a common control and distribution architecture that incorporates both fossil fuels and renewable energy for centralized, distributed, and platform delivery. This strategy assumes an expanded use of energy storage devices to increase the penetration of emerging renewable energy technologies into daily Army operations. In support of this strategy, an early objective is to draft a prototype master plan for ultra-low-energy community systems suitable for field testing at selected Army installations.

A workshop bringing together leading energy research scientists, engineers, industry experts, and military users was convened to define the

technology required to implement this vision. The purpose of the workshop was to emphasize a combination of selected technologies needed to implement the concept of an *energy-efficient city*, as presented by the keynote presenter, Dr. Reinhard Jank (Figure 1-1).

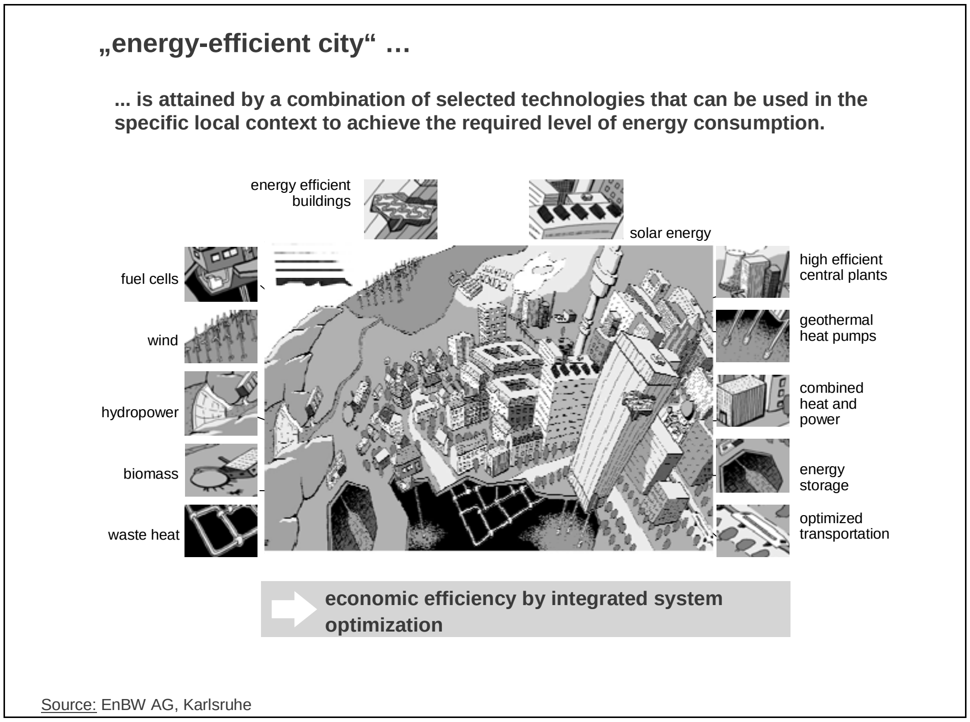

Figure 1-1. The energy-efficient city concept as depicted by Dr. Reinhard Jank.

1.2 Objective

The objectives of the workshop were to:

- characterize the broad portfolio of technologies needed to achieve Net Zero Energy (NZE) community systems for military emplacements and installations at all scales of organization
- identify the current state of the art in critical technical areas and gaps in the science that present barriers to ultra-low-energy solutions and their integration for unprecedented energy efficiency
- develop recommendations to address future research requirements and other efforts that will be required to establish effective NZE systems.

1.3 Approach

Individual workshop sessions were conducted to address the seven technical thrust areas determined to be central to the development of integrated next-generation NZE technology systems:

- renewable energy
- thermal and electrical energy storage
- power and energy architecture
- physical architecture
- energy conservation
- building envelope and materials sciences
- tool and system analysis methodologies.

The presentations summarized significant research findings and applied initiatives. The technologies within each topical area were discussed with respect to four central issues:

1. the state of technology maturity
2. technical barriers to the next generation of solutions
3. prospective applied research projects to overcome technical barriers
4. opportunities to network multiple technologies into viable NZE solutions military facility and logistical operations.

The workshop hosted approximately 80 participants from leading research universities, U.S. Department of Energy national laboratories, domestic and international energy industry groups, the Office of the Secretary of Defense (OSD), U.S. military facility commands and research organizations, and others from key stakeholder groups and prospective user communities.

Links to the original workshop presentation materials may be found at http://dodfuelcell.cecer.army.mil/NZE.php, and a detailed list of the agenda and presenters is provided below.

First-day agenda, 2 February 2009.

Start	End	Time	Activity	Location
13:00	13:30	0.30	Arrive / Sign in	Crowne Plaza Hotel, The Foothills Conference Room
13:30	14:00	0.30	Fort Carson NZE Roadmap and Plan, Vincent Guthrie, Ft, Utility Programs Manager	Crowne Plaza, The Foothills Conference Room
14:00	14:45	0.45	Travel and Security (through gate) to 2MW PV Array	Fort Carson
14:45	15:30	0.45	2 MW PV Array Site Visit, Vincent Guthrie, Fort Carson Utility Programs Manager	Fort Carson
15:30	15:45	0.15	Travel to Solar Wall	Fort Carson
15:45	16:15	0.30	Solar Wall Site Visit, Vincent Guthrie and Scott Clark (Installation Energy Manager)	Fort Carson
16:15	17:00	0.45	Return to Hotel	Crowne Plaza Hotel

Detailed workshop agenda and speakers, 3 February 2009.

Start	End	Time	Activity	Speaker
08:00	08:15	0:15	Arrive / Sign in	
08:15	08:30	0:15	Welcome / Introductions/ Overview of Meeting and Expectations	Dr. Tom Hartranft / PERTAN Group/All
08:30	09:00	0:30	Keynote Address: Dr. Reinhard Jank, “Energy-Efficient Community Systems”	Dr. Reinhard Jank
09:00	09:20	0:20	Session I: Renewables for NZE, Session Chair: Dr. Andy Walker, NREL, “Renewable Energy Optimization for NZE”	Dr. Andy Walker
09:20	09:40	0:20	Topic I: Dr. R. Boehm, UNLV Energy Center, “Zero Energy Buildings”	Dr. R. Boehm
09:40	10:00	0:20	Topic 2: Heidi Anne Kaltenhauser, Concurrent Technologies Corporation, “Case Study of Privatized NZE Homes at Fort Campbell”	Ms. Heidi Anne Kaltenhauser
10:00	10:20	0:20	Break	
10:20	10:40	0:20	Topic 3: Cecile Warner, NREL, “Building-Integrated Photovoltaic”	Mr. Cecile Warner
10:40	11:00	0:20	Topic 4: Tony Jimenez, NREL, “Wind Energy”	Mr. Tony Jimenez
11:00	11:20	0:20	Panel Discussion	
11:20	11:40	0:20	Session II: Thermal and Electrical Energy Storage for NZE Session Chair: Dan Rastler, EPRI	Mr. Dan Rastler
11:40	12:00	0:20	Topic 1: Energy Storage for Wind Energy Integration and Smart grid	Mr. Frank Novachek
12:00	13:00	1:00	Lunch: No Host	

Start	End	Time	Activity	Speaker
13:00	13:20	0:20	Topic 2: Energy Surety Approaches for Military Applications	Mr. John Boyes
13:20	13:40	0:20	Topic 3: Thermal Energy Storage	Mr.Brian Parsonnet
13:40	14:00	0:20	Topic 4: Scott Duncan, "An Overview of Various Cooling Energy Storage Technologies"	Mr. Scott Duncan
14:00	14:20	0:20	Panel Discussion:	
14:20	14:40	0:20	Break	
14:40	15:00	0:20	Session III: Power and Energy Architecture for NZE, Session Chair: Dr. Bob Lasseter, UW – Madison	Dr. Bob Lasseter
15:00	15:20	0:20	Topic 1: UW – Madison, Electrical Systems and Loads for Sustainable Buildings, Dr. Tom Jahns,	Dr. Tom Jahns
15:20	15:40	0:20	Topic 2: Combined Heat and Power	Dr. Clifford Haefke
15:40	16:00	0:20	Topic 3: GEF, “Thermal Management”, Dr. Stephan Richter	Dr. Stephan Richter
16:00	16:20	0:20	Topic 4: Biofuels and Bio-Energy on U.S. Military Basis	Mr. Chris Zagarlicke
16:20	16:40	0:20	Panel Discussion	
16:40	17:00	0:20	Session IV: Physical Architecture for NZE; Session Chair: Dr. Tom Hartranft	Dr. Tom Hartranft
17:00	17:20	0:20	Topic 1: Katrin Klingenberg, Executive Director and Lead Designer, Ecolab and Passive House USA	Ms. Katrin Klingenberg
17:20	17:40	0.20	Topic 2: Berthold Kaufmann, Passivhaus Institut, "Passive houses world wide basic conception and hints for adaption to special climatic regions"	Mr. Berthold Kaufmann
17:40	18:00	0.20	Topic 3: Georg Zielke, Architekturbüro Zielke Passivhäuser: "What can be done in Passive Housing in the future and in which way of construction?"	Mr. Georg Zielke
18:00	18:20	0.20	Open Forum to discuss the Army’s unique challenges and requirements. End of Day One, Discussion Topics for Day Two	Dr. Tom Hartranft

Detailed workshop agenda and speakers, 4 February 2009.

Start	End	Time	Activity	Speaker
08:20	08:40	0:20	Review of Day One Discussions and Preview of Day Two	Dr. Tom Hartranft
08:40	09:00	0:20	Session V: Energy Conservation for NZE. Session Chair: Alexander Zhivov, USACE,ERDC-CERL: "Energy Conservation Technologies for NetZero Buildings"	Dr. Alexander Zhivov
09:00	09:20	0:20	Topic 1: Heat Recovery/ Chilled Water Optimization Scott Duncan	Mr. Scott Duncan

Start	End	Time	Activity	Speaker
09:20	09:40	0:20	Topic 2: Alan Gillan and Valeriy Maisotsenko, Coolerado: "M-Cycle beyond Comfort Cooling"	Mr. Alan Gillan
			Topic 3:	
09:40	10:00	0:20	Topic 4: John Shonder, ORNL: Heat Pump Optimization	Mr. John Shonder
10:00	10:20	0:20	Topic 5: Advanced lighting systems, Phillips, Ltd	Mr. Gert Brunining
10:20	10:40	0:20	Panel Discussion	
10:40	11:00	0:20	Break	
11:00	11:20	0:20	Session VI: Building Envelope and Materials Technology for NZE, Session Chair: Mr. Bill Rose	Mr. Bill Rose
11:20	11:40	0:20	Topic 1: Flexible Photovoltaic's for Deployed Basis	Mr. Steven Tucker
11:40	12:00	0:20	Topic 2: Materials: Foam, Airtightness, Compliance	Mr. Henri Fennell
12:00	13:00	1:00	Lunch: No Host	
13:40	14:00	0:20	Topic 3: High Performance Aerogel Insulation for Shelters	Ms. Elizabeth Swisher
14:00	14:20	0:20	Break	
14:20	14:40	0:20	Session VII: Tools and Systems Analyses Methodologies for NZE Session Chair: Dr. Jacob Brouwer, University of California	Dr. Jacob Brouwer
14:40	15:00	0:20	Topic 1: Modeling, Simulation, and Measurement of Building Energy Performance.	Mr. Ron Judkoff
15:00	15:20	0:20	Topic 2: Automatic Disaggregation of Electrical Loads by Nonintrusive Appliance Load Monitoring.	Dr. Lucio Soibelman
15:20	15:40	0:20	Case Study of NZE Design in Affordable Housing	Mr. James Meacham
15:40	16:20	0:40	Panel Discussion	
16:20	16:50	0:30	Final Wrap-up and Close	Dr. Tom Hartranft

2 Issues in the Development of NZE Military Installations

2.1 Planning initiatives and vision

Reducing the energy demands of military installations without compromising the mission of its tenants is a major goal of the U.S. Army. Lower energy demands result in smaller supply requirements which in turn translate into less vulnerable Army garrisons and more secure installations. Following the California energy shortages of 2000, Congress directed the DoD to assess the potential for renewable resources on and near DoD facilities. The study was designed to evaluate the potential for renewable asset development and civilian energy reliability and security. The study resulted in two reports to Congress issued in March 2005; the DoD Renewable Energy Assessment and a companion implementation plan (DoD 2005a, 2005b). The implementation plan identified potential for DoD meeting the equivalent of up to 50% of its electricity use from renewable energy sources by 2025 if an aggressive program was pursued and utility budgets were increased. The report was used to establish a 25% by 2025 renewable goal in a DoD memorandum dated November 18, 2005 (DoD 2005c). This goal is higher than that of EPAct (Energy Policy Act 2005); however, it was developed in a way that makes sense for DoD and Army. It was established using a definition of renewable energy that includes use of renewable energy to displace conventional energy resources used for thermal uses onsite as well as for power generation. The focus is on reducing primarily fossil fuel use, including those used for thermal energy needs.

To assist in this emerging vision, the U.S. Army Assistant Chief of Staff for Installation Management (ACSIM) has issued planning guidance for the development of five NZE installations by Fiscal Year 2015 (FY15). These NZE installations can produce as much or more energy than they consume. Presently, Department of Energy (DOE) NZE initiatives focus on individual buildings, not installations at the scale of a military garrison, when addressing the need for lower energy demand. Although building energy consumption is an important part of the overall energy demand of military installations, Army garrisons offer additional NZE challenges and possibilities. Military installations may typically offer a higher degree of

load aggregation than the one provided by a single building. And military installations may also require a higher degree of energy diversification than that required by a single building. Most significantly, installation NZE initiatives significantly impact the energy security and energy fungibility goals of the U.S. Army in three ways by:

1. reducing energy consumption
2. increasing the use of renewable alternative energy sources
3. creating a culture of energy accountability.

Current worldwide energy prices and oil supply conditions make these goals more essential than ever.

2.2 Current approach

The Army's present implementation of renewables is currently focused on encouraging third-party financing to pay for installation projects up front, with a government commitment to pay back these investments using long-term funding (over 20 years) derived from annually funded operations and maintenance budgets. This third-party financing has taken the form of a few energy services companies (ESCOs) pursuing several small renewable projects for installations in a somewhat random fashion. A second alternative is that of the Army encouraging utility companies to build a handful of large, onsite power parks with 200+ MW of solar, wind, or geothermal power, depending on climate zone. By doing so, the Army is then leveraging this type of third-party financing by offering its extensive installation lands for utility siting. These huge renewable power parks are expected to profitably deliver electrical power directly to the nearby utility company grid, and in return, provide free or much-reduced electricity rates to the installation.

However, neither ESCO-type projects nor the huge power park approaches are optimally cost effective or technically elegant solutions. Neither approach facilitates economical penetration of renewables over a wide spectrum of Army installations and FOBs, nor are they designed to be integrated with energy storage and ultra-low-energy facilities. Further, these types of solution are costly over the long term, and they expose the Army to commercial enterprise risks and an unpredictable world financial market needed to finance these costly projects. This approach also excludes 90% of Army installations from benefiting from renewables implementation because private companies view most installations as high risk for

economic payback. Such site-specific solutions require costly extensive engineering for each site; costly environmental review and certification; and do nothing for deployed base energy security needs.

What is required is a suite of ultra-low-energy solutions that are adaptable for any Army complex, fixed installation, or forward emplacement on the basis of local climate, mission requirements, facility characteristics, etc. By establishing a uniform ultra-low-energy supply, demand, and storage architecture, the Army will reduce risk perceived by third-party contractors so that many installations will be pursued by them for NZE-type implementations.

3 Conference Presentation and Discussion Summaries

This chapter summarizes the proceedings of the workshop as follows:

- Section 3.1, Fort Carson NZE installation presentation and tour
- Section 3.2, Keynote presentation
- Section 3.3, Renewables
- Section 3.4, Thermal and electrical energy storage
- Section 3.5, Power and energy architecture
- Section 3.6, Physical architecture
- Section 3.7, Energy conservation
- Section 3.8, Building envelope and materials sciences
- Section 3.9, Tools and systems analysis methodologies.

3.1 Fort Carson NZE installation presentation and tour

The presentation and tour by Vince Guthrie and Scott Clark revealed the initial findings of one of the Army installations identified to reach NZE goals by the year 2030. Not including housing, Fort Carson currently uses approximately 145,000 mega watt hours (MWH) of energy per year and 1,200,000 KCF of gas.

The Fort Carson energy demand is increasing. Current plans for renewable energy include solar, wind, ground source heat pump, biomass fuel, and passive solar walls.

A $12 million dollar, 2 MW solar array was the seventh largest in the country when it was installed at Fort Carson in December 2007. It meets between 2% and 3% of Fort Carson's total energy needs at this time. It is directly connected to the existing utility grid and therefore currently provides no back-up capabilities if the grid goes down. The Passive Solar Wall installed on the exterior of a high-bay distribution and warehouse has slightly reduced HVAC demands on a single facility.

Fort Carson representatives indicated that there is likely to be a need to reach outside the base to the surrounding community and energy service companies to meet NZE goals.

Replacement of boilers, lighting systems, HVAC systems and other energy items with more efficient systems to reduce energy loads is part of the Fort Carson NZE plan. Similarly, greening facilities and building new facilities that are highly energy efficient are a necessary and critical element of the Fort Carson NZE Plan.

3.2 Keynote presentation: *Overview of NZE Systems and their Integration for Energy-Efficient Community Systems*

The workshop keynote speaker, Dr. Reinhard Jank, is the Operating Agent of the International Energy Agency's (IEA) Annex 51 Energy-Efficient Communities Committee as well as the energy manager for the recently reconfigured NZE plan for the city of Freiburg, Germany. As the energy manager for Volkswohnung, a housing company that manages 14,000 dwelling units in 460 buildings, he oversees an annual energy retrofit investment budget of about €25 million a year. Dr. Jank began his presentation laying out a clear scientific connection between fossil fuel energy carbon dioxide issues and increased climate change problems that, if left unabated, could lead to tumultuous world conditions that poise significant security threats to the United States and its allies.

A resident of Germany, which has a collective understanding of the need for energy efficiency, Dr. Jank drew from many well-established, advanced energy-efficient plans for buildings, communities, and cities. As the leader of the IEA's Annex 51 Energy-Efficient Communities Committee, Dr. Jank provided a synopsis of community system energy plans from Japan, The Netherlands, Canada, Germany, and France. Although the United States is part of the IEA, it is not a listed member of the Annex 51 Energy-Efficient Communities, and he mentioned that so far, no U.S. community system energy plans were submitted through the IEA (Figure 3-1).

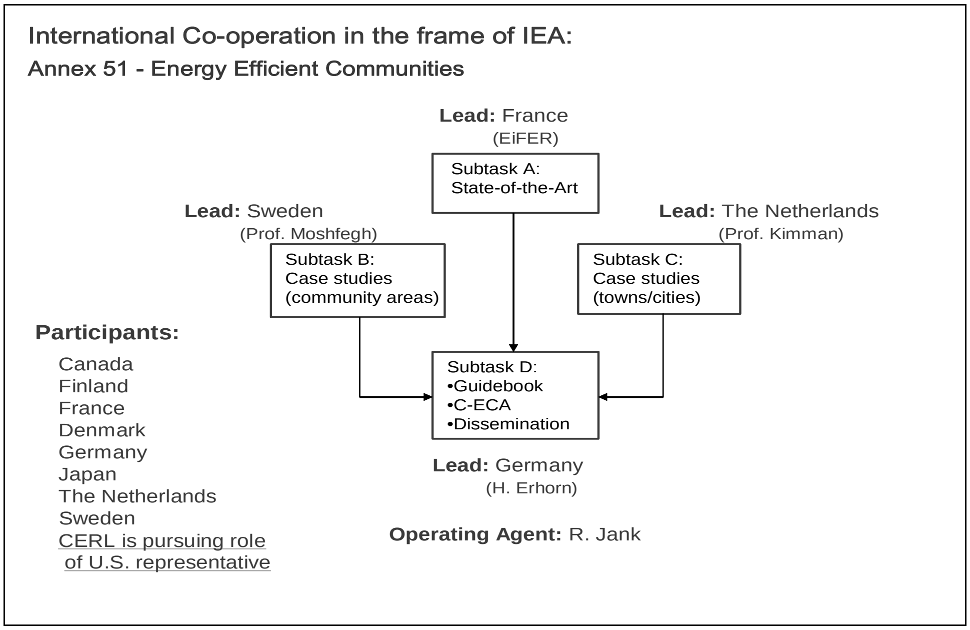

Figure 3-1. International cooperation in the frame of IEA (Dr. Jank).

Since 2004, Dr. Jank spent two years analyzing and redeveloping the City of Freiberg's NZE plans, first established in 1991. Dr. Jank explained how there were initially over-optimistic hopes placed in the possibility of achieving NZE status with the use of a single renewable energy source — solar power. Initially this involved extensive application of solar collectors in massive arrays and on individual buildings, however energy usage continued to increased and by 2005 the city had lost its NZE gains. During this period, as one example, Volkswohnungs carbon-based building stock energy consumption was reduced from 259 kWh/m^2 in 1990 to 137 kWh/m^2 in 2005, so there still needs to be a further 71% reduction in carbon-based energy consumption to achieve NZE goals and associated carbon reductions by 2020. To meet the community-wide goals, a comprehensive energy plan expanding beyond solar energy was devised by Dr. Jank, who initiated a 2-year study and pilot programs that demonstrated a more diverse NZE approach. The plans include extensive energy conservation methods, improved standards, modularization, centralized combined heating and power plants with extended district heating, improved metering and controls, multiple renewable energy sources, decentralized cogeneration plants, waste energy plants, scheduled inventory and assessment of results, cooperation among utilities, improved transportation planning and other methods, including human behavior modification (Figure 3-2).

Targets:
- reduce energy demand
- improve efficiency
- increase use of renewables

→ Tasks:
➢ improve buildings efficiency
- refurbishment
- standards for new buildings
- optimization of technical equipment

➢ install decentralized energy supply
- cogeneration
- waste heat
- renewables

➢ drive behavioral changes

➢ improve transport efficiency by
- using efficient cars
- change from car to bike / walk
- extend public transportation

Figure 3-2. Targets and tasks for achieving energy-efficient communities (Dr. Jank).

Dr. Jank noted that there is no general solution to achieve NZE goals, and that long-term, site-specific plans involving many people and institutions are necessary to be successful. He continued by observing that there exist many alternatives for the application of energy conservation / renewables technologies. One is therefore confronted with a problem of selection, from many viable alternatives, those technologies and potential R&D fields that will net the best results, in the shortest time, from available funds and prevailing cultural values and constraints. His guidance for achieving this is to "learn-by-doing"— what works for a particular situation, and what does not. In doing so, one would employ the best technologies at an installation for the tasks at hand and develop and centralize the required knowledge to accomplish these diverse ends.

Dr. Jank added the following important observations.

At the NZE workshop, most of the papers were not particularly directed at R&D technology, but instead addressed technologies that are already available "off the shelf." Their use is hindered by many diverse barriers (e.g., political, cultural, knowledge-based), but lack of technical maturity is not the barrier in these cases. (Examples of mature technology include wind energy, cogeneration, "Passivhaus" buildings, ground-coupled heat pumps, heat recovery in ventilation systems, smart homes, use of biomass etc.)

In Dr. Jank's opinion it is more cost-effective to wait for new R&D results from advanced photovoltaic (PV) systems (thin film systems using optimized power electronics) than using the PV technology presently available today (Figure 3-3). He believes present PV technology is far too expensive on a cost/benefits basis, based on comparing the cost of PV installations with the benefits that would have been available, had the same amount of money been spent for other options of energy conservation or renewables.

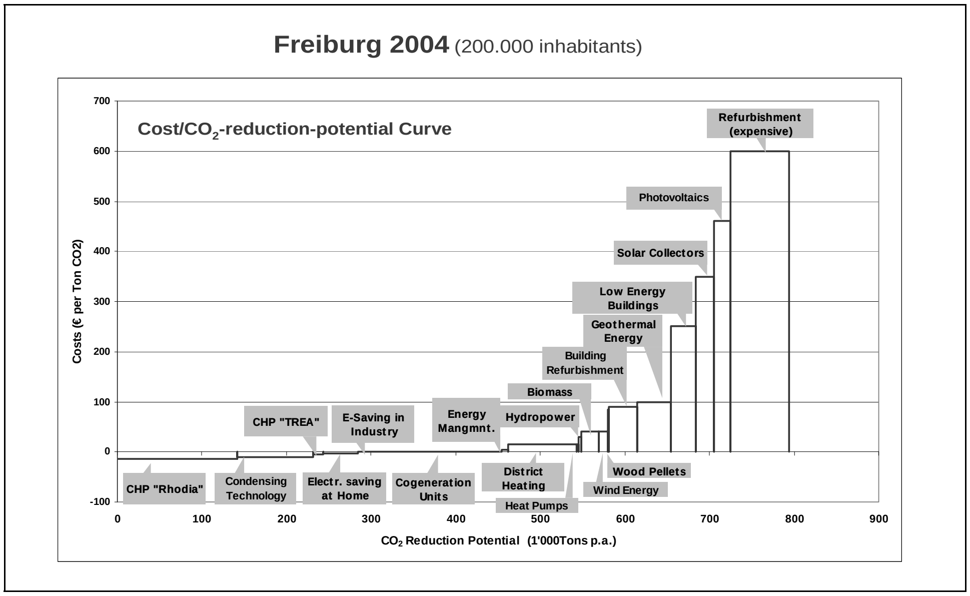

Figure 3-3. CO_2 reduction potential (Dr. Jank).

For solar collector systems, attention to details is primal, and can make or break the utility and life cycle issues of such systems. These systems have proven track records throughout Europe, but require knowledgeable designers and installers of the primary and secondary systems.

Cogeneration technology (combined heat and power, CHP) is a fully mature and commercialized technology. U.S. manufacturers, such as Waukesha, Caterpillar, or General Electric (via its subsidiary Jenbacher) are offering their products in Europe and making good business, others are MAN (Augsburg) or KHD (Cologne) or Waertsilae (Finland). Even "micro-cogeneration devices" are available now, with capacities of about 1 kWel and 5 kWth, offered in Europe (www.whispergen.com) ; again, non-technical barriers and mind-set issues exist.

The concept of improved standards, modular solutions, and increased energy conservation of existing buildings can help individual buildings achieve greater efficiency. However, it is difficult to have existing buildings

achieve NZE goals on their own. Dr. Jank notes that because the replacement rate of old, inefficient buildings, with new, efficient buildings is a slow process, 80% of all buildings in Freiburg will still be of older stock by the 2020 target data. Therefore, NZE can not be met with efficiency increases alone; there must be efficiency gains on the supply side.

Present statistics for German buildings indicate a decrease in total energy consumption, while corresponding total energy consumption in the United States continues to increase. However, both countries are similar in that approximately 50% of total energy is consumed by buildings, with industry and transportation each consuming about 25% of total energy. This further emphasizes that the greatest strides toward NZE bases and installations can be achieved through appropriately planned and properly funded community systems approach. This systems approach to achieving NZE goals is based upon economies of scale involving many buildings, and can best be implemented using a community-wide approach that focuses on the details and architecture of the energy infrastructure. In this paradigm one can readily realize efficiencies through district heating, CHP, low exergy technologies, waste heat recovery, heat pumps, efficient cars, extended public transportation and renewables. These are well-established and mature technologies, fully capable of systems integration, higher implementation rates, meeting 60 – 80 % target reductions in fossil energy consumption, and reduced CO_2 emissions.

Dr. Jank suggests the following steps outlining the systems approach to an energy-efficient community:

1. community energy/CO_2 balance, Building-Architecture-Universal scenario, long-term targets
2. portfolio of conservation/renewable measures locally available
   a. cost
   b. potentials
3. system integration: long-term
4. implementation strategy: projects, financing, organization
5. monitoring / evaluation / feedback / adjustments.

Dr. Jank emphasized the importance of R & D to achieve NZE and described the following, in terms of demand and supply:

- Demand
  - walls and roofs (including coupling to the environment)
  - pre-fabrication
  - smart buildings
  - battery-less sensors/actuators
  - low exergy buildings
  - lighting, electrical appliances

- Supply
  - decentralized forms of electrical heat supply
  - medium-sized cogeneration plants (1-10 MW)
  - industrial waste heat utilization
  - wood chip plants with electrical generation
  - wind parks (10-100 MW_{el})
  - solar-thermal power plants (10-20 MW_{el})
  - bioenergy plants (10^2-10^3 kW_{el}) — biogas, second-generation biofuels
  - small/micro cogeneration plants (10^1-10^3 kW_{el} scale)
  - small-scale wind generators (~1 Mw_{el})
  - wood pellet boilers (10^1-10^3 kW_{el} scale)
  - ground-coupled heat pumps
  - solar heating/cooling
  - PV

The above items denote market deployment gap with technology available.

Finally, Dr. Jank discussed several opportunities for R&D.

He considers solar cooling to be an important option that has been largely neglected (however, pilot plants employing an absorption cycle are in operation in several places). He also mentioned that the manufacturing community considers there is still much room for technical improvements for high-temperature collectors (> 100 °C) which are required for solar cooling systems. In certain climates like Las Vegas, solar cooling would be a viable alternative (avoiding almost all the electricity needed for cooling).

Biomass is a field where there is still much development potential. Biogas in particular is a technology which is considered to be mature. Presently, it can be obtained from a range of manufacturers (such as Schmack Gmbh in Schwandorf, GET project in Kiel, Haase Biogas-Anlagen in Neumuenster

and several others, also in The Netherlands, Denmark, and Austria). Over 4,000 biogas plants are in operation in Germany, with an aggregated capacity of about 700 MW_{el}. However, knowledgeable investigators such as Prof. Scheffer from the University of Kassel, have observed that while development of biogas technologies is far from being finished, major improvements are still expected in terms of land use for biofuel crops, process performance, and costs. Compared to bio-ethanol, the eco-footprint of biogas is much better. Biogas plants using bio-crops rather than poplar forests (to produce solid fuels) may be the best use of biomass so far. The development of a "biomass competence center," co-operating with universities and industry, is a good idea in Dr. Jank's opinion.

Passivhaus is useful and demonstrated technology, but adaptation to U.S. climates and behavior of U.S. users is still necessary. Again, this is a case for "learning by doing." Pre-fabrication can provide big cost-saving potential (Passivhaus, building retrofit) with increased usage, and has been brought to its perfection by the approach developed by Annex 50 (Mark Zimmermann, Switzerland (http://www.ecbcs.org/annexes/annex50.htm). In particular, U.S. Army installations could provide a large cost-decreasing potential because of the large number of buildings and their (supposed) standardized architecture.

3.3 Renewables

3.3.1 Summary

While significant developments have occurred in each segment of renewable energy generation, there is a need for advanced modeling, metering and controls to successfully deploy meaningful, wide-scale renewable energy applications. Furthermore, extensive grid integration and management science is needed to achieve seamless interoperability of the multiple, renewable-energy generation sources required to provide energy security to bases and installations. Figure 3-4 shows each topic presented during the renewables session.

Session I: Renewables for Net Zero Energy Installation

Session Chair: Dr. Andy Walker, NREL, "Renewable Energy Optimization for Net-Zero"
Topic I: Dr. R. Boehm, UNLV Energy Center, "Zero Energy Buildings"
Topic 2: Heidi Anne Kaltenhauser, Concurrent Technologies Corporation, "Case Study of Privatized Net-Zero Homes at Fort Campbell"
Topic 3: Cecile Warner, NREL, "Building-Integrated Photovoltaic"
Topic 4: Tony Jimenez, NREL, "Wind Energy"

Figure 3-4. Topics in renewables.

3.3.2 Observations

Renewable energy options have been possible on a commercial basis for more than 50 years. Extensive studies on individual homes and buildings are providing the basis of understanding how to deploy renewable energy on a community system level, but research is needed to understand successful implementation of secured renewable energy systems on a community system level.

According to Dr. Andy Walker, renewable energy technologies are generally some mixture of solar, wind, air and water solar-preheat or reuse of available biomass. Within the context of NZE, an efficient usage of these renewables requires the solution to a nonlinear, multi-parameter maximization routine. Such a routine must simultaneously maximize the solution space of the integrated community, with respect to the following:

- minimized life cycle and operations and maintenance (O&M) costs
- accounting for the size and variability of a particular renewable at a given location
- amounts and dissimilar nature of the individual renewable components mix
- adequate real-time communication between energy sources and sinks
- storage and demand-related issues associated with biological, electrical, and thermal systems
- prevailing utility rates that are subject to discount and fuel escalation rates

- state, utility, and federal incentives.

A key component in the general solution of these constraints is the Dispatch Algorithm, as shown in Figure 3-5. This algorithm attempts to communicate between the various constraints in real time, so as to maximize some function, which for the NZE is minimal energy usage. Presently, approximate solutions exist for only the most simple and restrictive subsets of this more general problem, which is the subject of intense research. The concept can help forecast how much renewable energy can be generated at a location relative to the demand of operations and the cost of renewable energy creation. The algorithm does not reflect energy demand or storage cost/benefit tradeoffs. Neither does the algorithm apply to forward operations. Also, Executive Order 13423, “Strengthening Environmental, Energy and Transportation Management,” requires energy plans to be based on total energy usage, not total costs. If more requirements continue focusing on improvements in energy efficiency as opposed to cost efficiency, there can be a benefit to developing similar algorithms based on optimal energy performance, not costs.

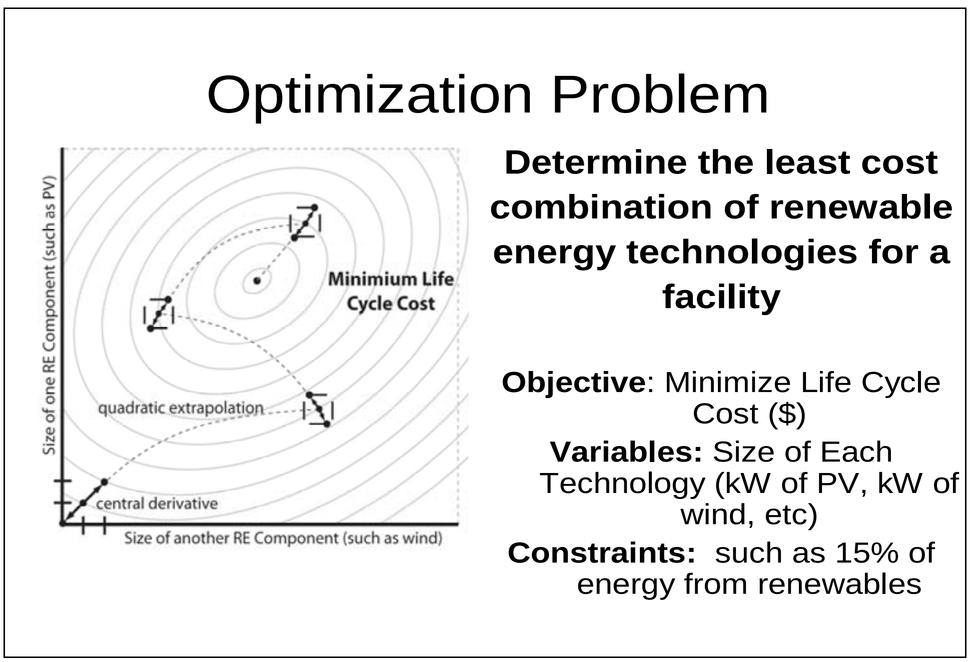

Figure 3-5. Optimization problem (Dr. Walker).

National Renewable Energy Laboratory (NREL) studies from 2007 indicate that research should focus on how large-scale production of renewable energy will effect electrical load changes on existing grids. It is suggested that research also be conducted on how individual system and

appliance loads can be monitored for understanding their cumulative impact on electrical grids. Dr. Walker described the best mix of renewable energy technologies as follows:

- renewable energy resources
- technology characterization
  - cost ($/kW installed, O&M cost)
  - performance (efficiency)
- prevailing utility rates
- state, utility and federal incentives
- economic parameters (discount rates)
- fuel escalation rates.

Studies presented are subject to specific regional conditions and indicate that comprehensive renewable energy opportunities need to be mapped globally in order to achieve proper readiness levels and homeland support of NZE goals. For example, the large summer cooling load in Nevada and similar climate zones makes the implementation of distributed thermal storage less effective than in northern regions. Also, wind condition global maps make it possible to quickly evaluate wind energy options for rapidly deployed forces.

The most optimistic projections of Building Integrated Photovoltaics (BIPV) production were met with BIPV flat panels would only provide 12 – 16% of 2007 winter and summer peak demand in the U.S. by 2015, and the cost would be high. Furthermore, the ability to successfully integrate all renewable energy into the grid and the impact on the grid is uncertain. Maintenance and durability issues also could be better understood, to ensure long-term success of large BIPV systems.

The capabilities of small, medium, and large wind energy generation are well understood, as are the main technical issues with wind energy generation. While two days of high winds can generate enough energy to meet needs for a week, storing the energy for when it is needed is still a major concern because there are no modular, plug-and-play solutions ready for wide-scale deployment. Development of integrated approaches with thermal storage or vast amounts of compressed air to power generators when wind speeds are low can be researched. Inverters and/or bi-directional converters can be developed to assist with battery storage opportunities for integrated, multi-power source generators.

3.4 Thermal and electrical energy storage

3.4.1 Summary

The path to NZE community systems needs to include a broad mix of traditional energy and renewable energy generation sources, connected across a smart grid that is supported with numerous energy storage systems. To achieve this, an integrated approach to energy generation, storage, distribution, management, and conservation is needed. Figure 3-6 shows each topic presented during the session of Thermal and Electrical Energy Storage.

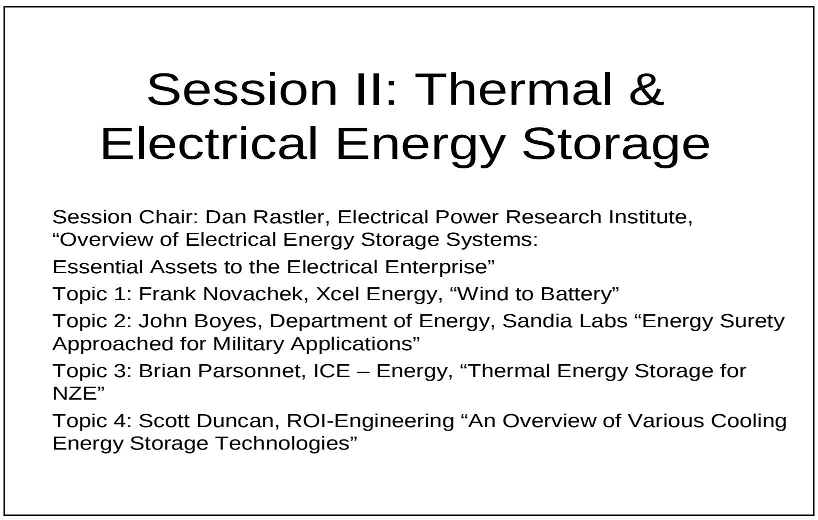

Figure 3-6. List of topics in Thermal and Electrical Energy Storage session.

3.4.2 Observations

As shown in Figure 3-7 presented by Mr. Dan Rastler, the U.S. electrical industry contributes 30% or more of the country’s carbon footprint and demand for electricity is projected to increase by 30% by the year 2030.

The size of the current U.S. annual consumption of electricity is large, on the order of 3800 TWh per year. For comparison, the New York metropolitan area uses approximately 90 TWh per annum (which is the combined equivalent of eight, 1400 MW light water nuclear reactors, each producing about 11 TWh per year). The Energy Information Agency projects that by 2030 the U.S. electrical consumption will have increased by another 1150 TWh.

Key Messages

The U.S. is in an Energy Crises > Transportation > Electric Power > Higher Electric Costs and Cost of Peak Power;

The Electric Sector Emits over 30% of the US GHG Emissions; A Full Portfolio of Supply and Demand Energy Solutions will be needed;

The Future Generation Mix will include a portfolio Variable Renewable Generation Sources;

The Electric Sector can not Inventory "Electrons" !

Energy Efficiency and advanced load management and control will be an essential part of the solution – enabled by a 'Smart Grid'

Numerous electric energy storage systems are available **today** for application in Zero-Net-Energy Applications

More Energy Storage Demonstrations are needed!

Electric Energy Storage is an Essential Asset in the Smart Grid

Figure 3-7. Key messages presented by Dan Rastler.

Furthermore, the electric power sector emits over 30% of the U.S. greenhouse gas (GHG) emissions, so that a full portfolio of supply and demand energy solutions will be required to address these issues. In particular, renewable sources of electrical generation and its storage will play a crucial future role in energy demand and GHG reductions.

Mr. Rastler showed that 1150 TWh of electricity would be needed by 2030 and presented the following scale of generation:

- one advanced light water nuclear plant (1400 MW, 90% CF) ~11 TWh
- one coal plant (500 MW, 80 CF) ~3.5 TWh
- one natural gas turbine (400 MW, 40CF) ~ 1.4 TWh
- one 100-MW wind farm (100 1-MW turbines, 40% CF) ~0.35 TWh.

Electric energy storage is an essential asset in the smart grid (more energy storage demonstrations are needed) as depicted in Figure 3-8, where an example of electric energy storage is shown as integration of locational opportunities of regulation, bulk energy, residential, transportable, distributed, and pad-mounted transformer storages in the electric enterprise.

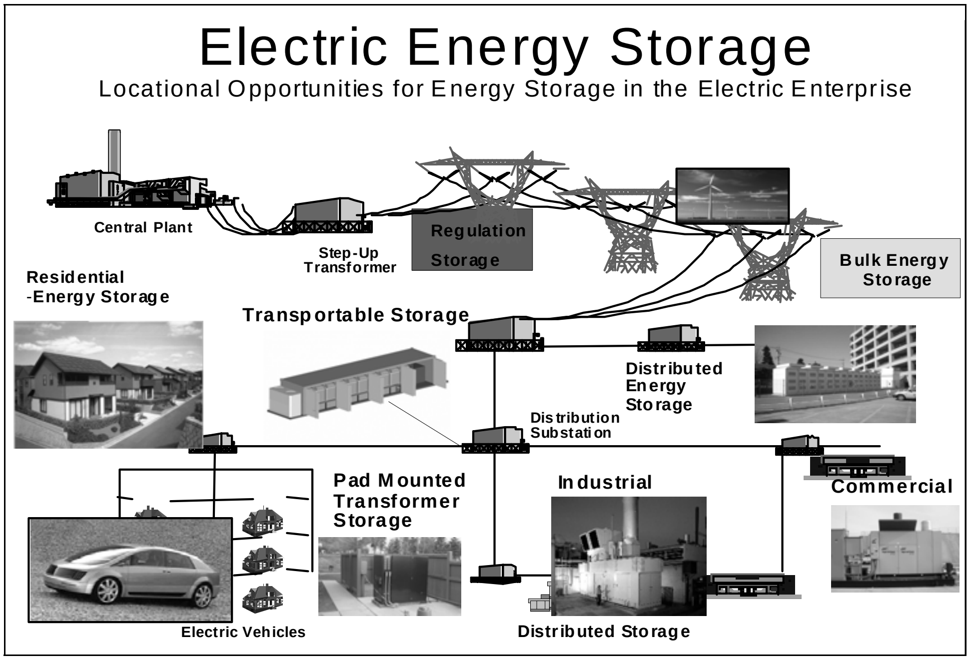

Figure 3-8. Electric energy storage (Dan Rastler).

"There is no way to build our way out of our current energy crisis," Rastler stated early in his introductory remarks. Integration will be needed of systems in an interoperable energy management system unlike anything that is currently in existence. Thermal and electrical energy storage will be a key to a balanced community system that assists peak loading shaving and creates buffer time.

A key issue is that of load leveling: 25% of U.S. distribution capacity and 10% of generation (transmission is similar) capacity is needed, at a cost of tens of billions of dollars, for only 400 out of 8,600 hours of each year (~5%) for those periods when power demand is excessive due to heat waves, etc. The electrical power system can realize enormous savings if these 400 hours and energy costs can be changed or moderated in some other way, such as the use of local renewables, and energy storage. The NZE concept for communities addresses the same short-duration, max power distribution by having dedicated energy storage and distribution architecture on site. Figure 3-9 shows different energy storage options of which energy management system (pumped hydro and CAES) is the most desirable type in terms of discharge time (y-axis) and system power rating (x-axis).

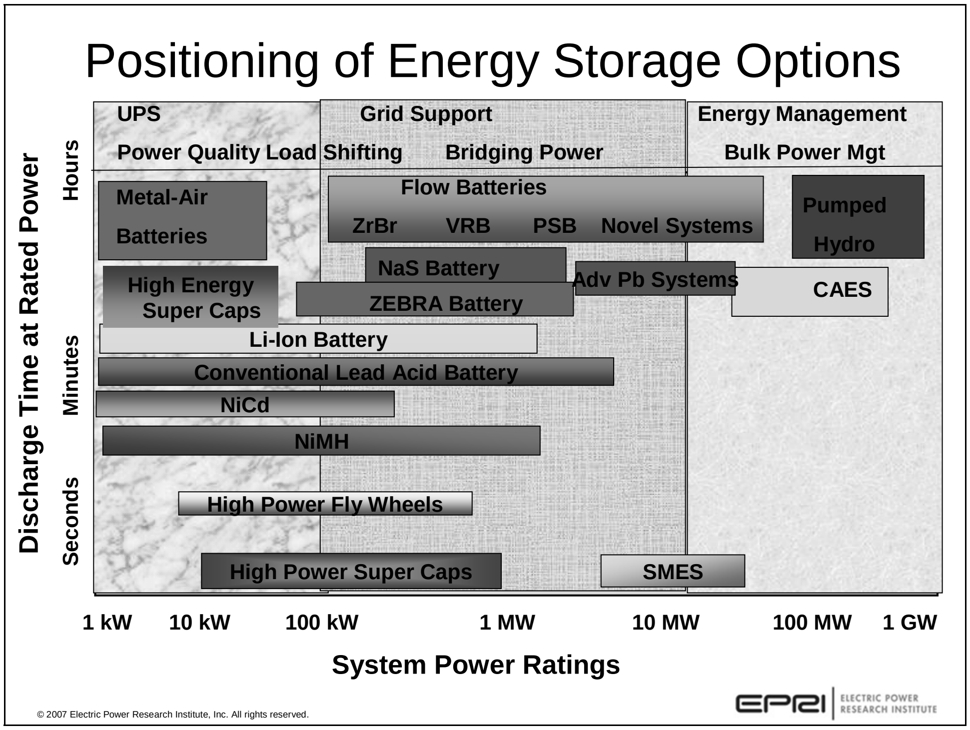

Figure 3-9. Positioning of energy storage options (Dan Rastler).

Pumped hydro facilities use off-peak electricity to pump water from a lower reservoir into one at a higher elevation. When the water stored in the upper reservoir is released, it is passed through hydraulic turbines to generate electricity. During such a release and during times of peak demand, the facility provides low-cost power, frequency regulation of the grid, and reserve capability. As shown in Figure 3-9, pumped hydro can store electricity for a long time and generate gigawatts of electricity.

Compressed air energy storage (CAES) compresses and stores air when renewable energy generation is high and demand is low. Figure 3-10 shows the second generation CAES (developed by ESPS) which uses simple-cycle combustion turbine module as an integral part of the plant. In 2008 dollars, the second generation design is about 33% less expensive (i.e., in the $460/kW to $530/kW range, which is an overnight construction cost in 2007 dollars) than the existing Alabama and German CAES designs, and operates with both reduced fuel costs and amount of CO_2 produced per kWh. The advanced design is also less expensive to operate and has less rotating equipment, resulting in expected high plant operational reliability/availability. The CAES – Adiabatic System is attractive for porous rock air stores because the air from the store does not go through any combustion process, making this option particularly attractive if one is concerned

about any chemical reactions taking place in the air store. The adiabatic option is of interest because no fuel is needed when the plant operates, as heat from the compression cycle is stored and used to preheat the air coming from the air store during the generation cycle.

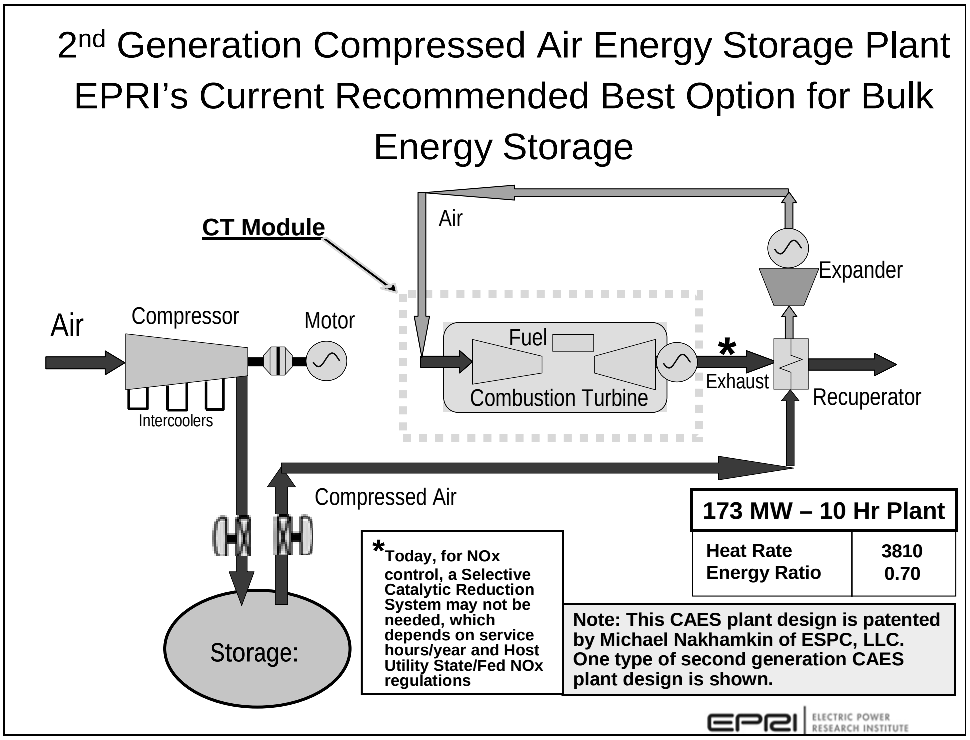

Figure 3-10. Second-generation CAES (Dan Rastler).

CAES Underground Air Store Siting: The underground geologic formations suitable for CAES in the United States are numerous because there are many gas and oil fields in the nation as well as salt water porous rock and hard rock sites. Depleted gas and oil fields could serve as reliable air storage sites for CAES, but many of these geological formations are also being considered as prospective carbon sequestration sites. Maps are available showing the location of these sites. A high-level map (see Figure 3-11) shows different sites to be used to store natural gas. These sites have proven to be stable and have excellent gas pressure tightness, and are thus attractive for potential use in CAES plants.

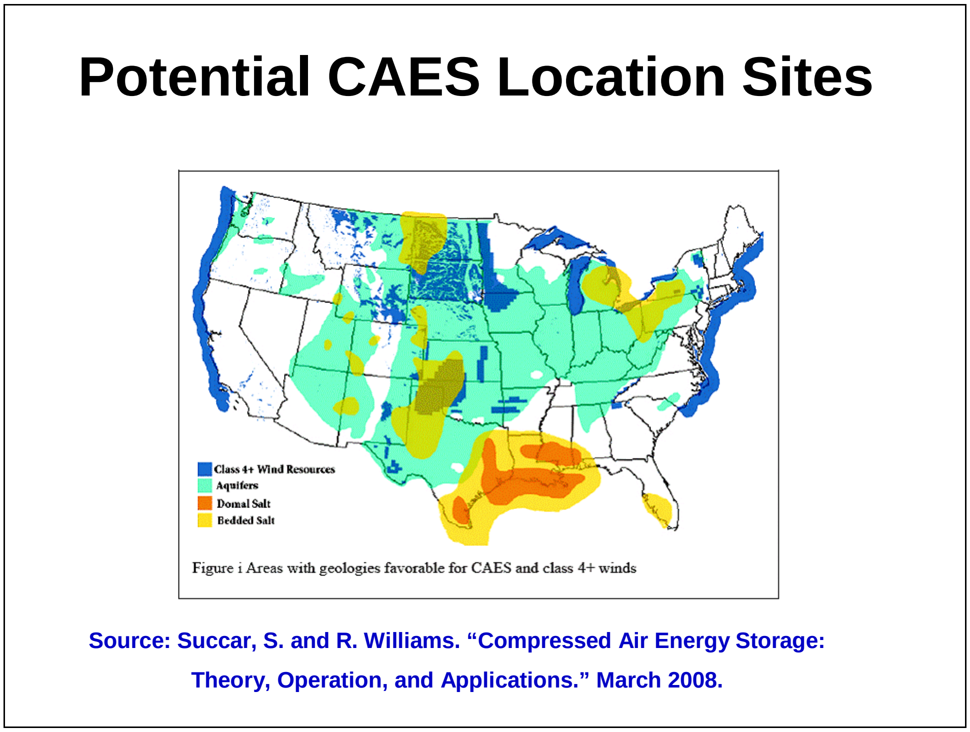

Figure 3-11. Potential CAES location sites (Dan Rastler).

CAES Above Ground Air Store Opportunities: Above ground air storage (for example, using high-pressure gas pipeline technology) can also be used for CAES storage, and there are a number of people reinventing this possibility, with each having their own specialized designs. Such systems are very attractive from the point of view that they allow CAES plants to be sited virtually anywhere because no underground geologic formation is needed. However, such systems are estimated to be more expensive (by about a factor of 5) than salt-based air storage caverns and porous aquifer-based air storage systems (capital cost of \$1500~1800/kW and added capital cost for one more hour storage of \$200~250/kW). It should be noted that future R&D on these above ground systems will likely reduce their cost; thus, this R&D topic should be investigated further.

Other storage possibilities include:

- Battery banks that allow storage of energy in large banks of NaS, Li-Ion, Zinc-Bromine, Lead Acid, and many other batteries types are being explored. One commonly used rechargeable type is the Lithium-ion battery, which has a low self-discharge rate of approximately 5% per month, compared with over 30% per month for common nickel metal hydride batteries (low self-discharge NiMH batteries have much lower

values, around 1.25% per month) and 10% per month for nickel cadmium batteries.

- Transportable battery banks the size of tractor-trailers that can be charged by a renewable source during off-peak times and moved where they are needed for specific uses during peak periods.
- Microgrid utilization of thermal and electrical storage can serve smart sensors, metering, and controls that can be adapted to traditional grid systems. "Much research will need to occur..." to take advantage of microgrid opportunities and potential benefits.

Thermal and electrical energy storage can provide considerable cost savings implications when implementing NZE plans for deployed installations and bases. Figure 3-12 shows current energy storage system costs in five different categories: Compressed Air Energy Storage, Pumped Hydro, Battery, Flywheel, Superconducting Magnetic Storage, and Super Capacitors. Super-Capacitors is the least cost ($300-450) per kW. However, when the number of hours is considered, large Compressed Air Energy Storage is the most economical option ($600-750). Note that all figures in Figure 3-12 are rough order of magnitude estimates and subject to change as better information becomes available. The total capital cost in Figure 3-12 includes power conditioning system and all equipment necessary to supply power to the grid. Not included are battery replacement costs, site permitting, interest during construction, and sustainable costs. While there are initial developments in conservation, metering, controls, generation, storage, and smart grid distribution, more collaborative research is needed to develop and integrate optimal solutions. Storage can be a critical part of the optimal solution, but it is only a part and needs to be studied in the context of a total community system approach to NZE plans.

Aspects of an integrated approach that can help meet energy goals is a virtual power system model that will allow better understanding of how thermal and electrical storage can best be used to optimize the most effective community system that avoids outages. Integration of electrical and thermal storage for distribution with smart grids will be critical to meet NZE needs.

A Snapshot of current Energy Storage System Costs

Energy Storage Technology Capital Cost Estimates (Aug, 2008 Dollars)

Storage Type (See all footnotes)	$/kW	$/kWh	H (See Footnote 4)	Total Capital Cost $/kW (See Footnote 1)
Compressed Air Energy Storage				
Large (100-300 MW), Below Ground Air Store -Salt Geology	590-730	1-2	10	600-750
Small (10-20MW), Above Ground Air Store	700-800	200-250	4	1500-1800
Pumped Hydro				
Conventional (1000 MW)	1500-2000	100-200	10	2500-4000
Battery (10 MW), See Footnote 3				
Lead Acid, commercial	420-660	330-480	4	1740-2580
Sodium Sulfur, projected	450-550	350-400	4	1850-2150
Flow Battery, projected	425-1300	280-450	4	1545-3100
Flywheel (10 MW) commercial	3360-3920	1340-1570	0.25	3695-4313
Superconducting Magnetic Storage commercial	200-250	650,000-860,000	1 sec	380-489
Super-Capacitors Projected	**250 - 350**	**20,000 - 30,000**	**10 sec**	**300 - 450**

Figure 3-12. A snapshot of current energy storage system costs (Dan Rastler).

When properly understood and controlled, stored energy can do more than reduce peak load crashes. Predictable energy load management allows more cost effective spot-market electrical purchases, more predictable fossil fuel purchases in uncertain markets, reduced “wear and tear” due to frequent starts and stops, based on fluctuating retail energy conditions, and allows more predictable power plant cycling in addition to achieving long-term environmental benefits.

Mr. Rastler summarized that electric energy storage is an essential asset in the smart grid:

- Wind power fluctuations: The intermittent nature of wind power means that it is harder to forecast than the fluctuations in electricity demand. Adding large quantities of wind power to power systems is therefore challenging. Thus, energy storage technology makes it possible for wind power plants to support the grid in the event of faults such as significant voltage drops.
- Short-term support for large-scale solar PV: solar photovoltaics exhibit short-term variable power output from cloud cover and other sources. Also, short-duration storage (seconds to minutes) can help mitigate

these fluctuations by reducing ramp rates because PV requires storage with high cycle life and power density but not long durations.

Mr. Rastler proposed an energy storage road map (Figure 3-13) for enabling management of peak loads, and intermittent renewables via smart grids. He listed important milestones as shown in the following areas:

1. Advanced 350 MW CAES Below Ground Demonstration (2010)
2. Advanced 15 MW CAES above ground demonstration (2012)
3. Adiabatic – CAES Evaluation Demonstration (2014)
4. Customer-Utility Side of Meter DG and Storage in Smart Grids: Li-ion , advanced flow batteries; advanced batteries (2014)
5. Utility Scale Storage for Grid Support-NaS, ZnBr, Li-ion, flow batteries (2014)
6. Aggregated DG and Storage Systems in Smart Grid (2014-15)
7. PHEV and Advanced DG and Electric Storage Systems (2023).

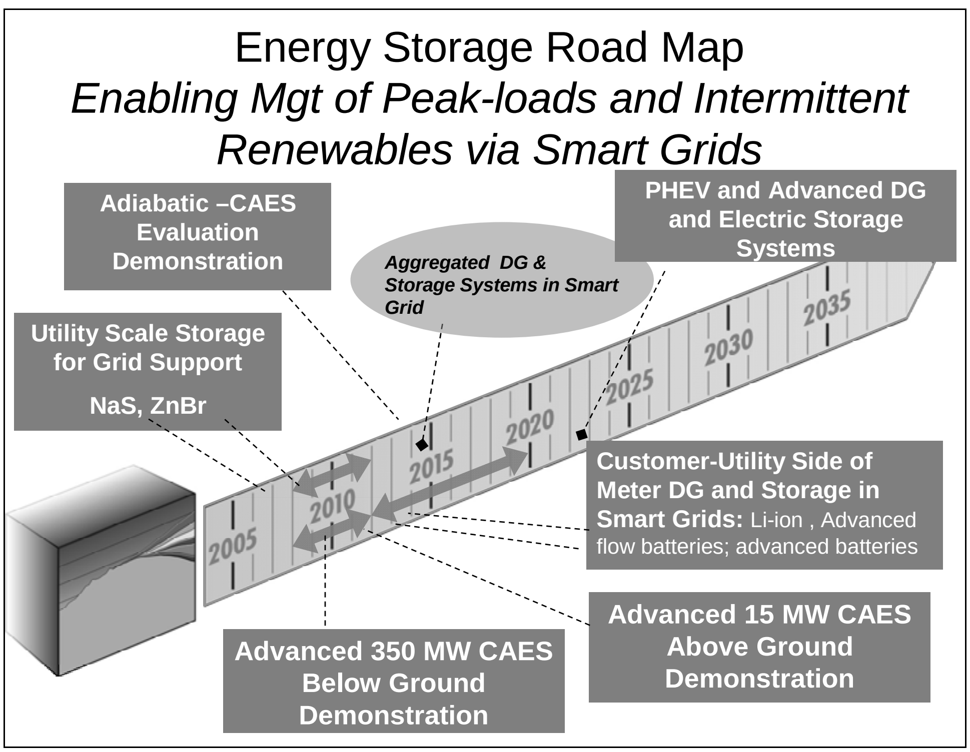

Figure 3-13. Energy storage roadmap (Dan Rastler).

At the end of his presentation, Mr. Rastler recommended more demonstrations to be built (1) to meet continuous energy demands, load leveling, and grid ancillary services in order to decouple demand from supply, (2)

microgrid and NZE applications, (3) smart-grid deployments, and (4) increase value and use of renewables.

3.5 Power and energy architecture

3.5.1 Summary

Development of technologies to enhance and rapidly implement microgrids is a major opportunity for significantly increased effectiveness in power and energy delivery to achieve NZE goals. Properly networked microgrids are highly adaptable to many energy generation sources and can accommodate outage of a single energy source in milliseconds, ensuring an almost imperceptible disruption of power service to any point on the installation grid. Effective integration of multiple onsite energy generation sources and storage, to satisfy both ultra-low-energy and high-energy needs from a single microgrid, can contribute to greater than 50% reduction in energy generation requirements for mission requirements at forward deployed bases and permanent installations. Figure 3-14 shows each topic presented during the session of power and energy architecture.

Session III: **Power & Energy Architecture**

Session Chair: Dr. Bob Lasseter, Prof. Emeritus, University of Wisc. – Madison Consortium for Electrical Reliability Technology Solutions "Power & Energy Architecture for NZE"

Topic 1: Dr. Tom Jahns, University of Wisconsin –"Electrical Systems and Loads for Sustainable Buildings"

Topic 2: Dr. Stephan Richter, GEF Ingenieur AG "Thermal Management"

Topic 3: Cliff Haeffke, Energy Resources Center, University of Illinois at Chicago "Combined Heat and Power"

Topic 4: Chris Zygarlicke, University of North Dakota "Biofuels"

Figure 3-14. Topics in power and energy architecture.

Existing theoretical microgrid research is ready to be implemented in Army-focused applied research and demonstrations. If properly funded, there is great promise that rapidly deployable NZE community system mi-

crogrid solutions can benefit forward deployed bases faster than most other opportunities. Key to the microgrid technology is integration of multiple energy generation, renewable energy generation, controls, metering, and modeling options as a comprehensive system.

3.5.2 Observations

In many energy distribution systems, a single source generates energy that is then distributed through a grid. If a disturbance occurs in the single energy generator, the grid goes down. In other energy distribution systems, there are multiple sources that generate energy, but they are dependently linked in a manner such that disruption in one energy generation source disrupts the entire grid.

Figure 3-15 shows an example of all systems to be considered in order to achieve the goal of NZE. Figure 3-15 also shows that energy loss occurs when energy is transformed to different types (electricity, cooling, heating, and fuels).

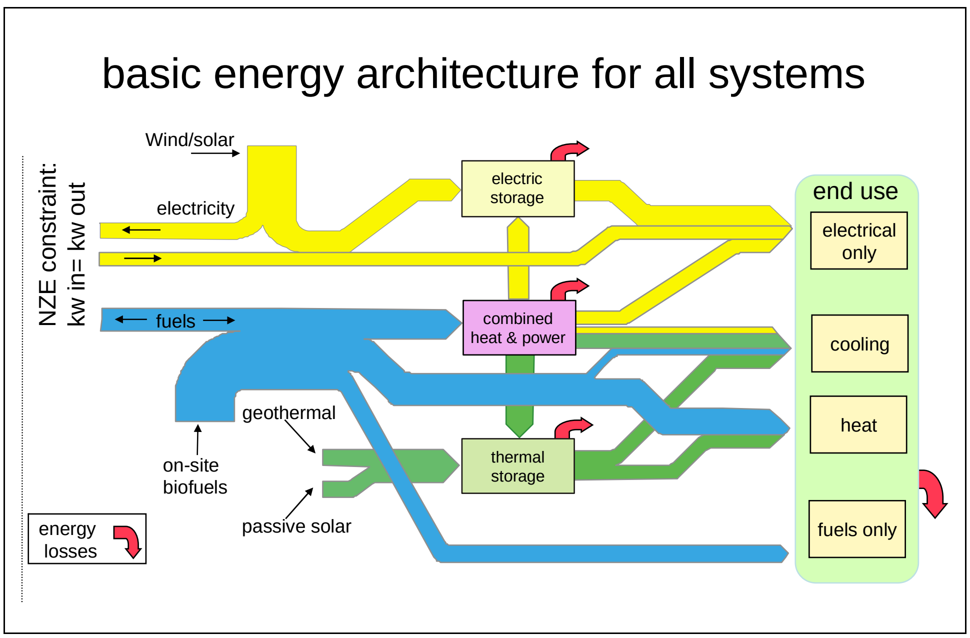

Figure 3-15. Basic energy architecture for all systems (Dr. Robert Lasseter).

3.5.3 Microgrid as a Model for the NZE Power and Energy Control Architecture (Dr. Robert Lasseter)

The conference speakers made the compelling case that economic, technology and environmental incentives are changing the face of electricity

generation and transmission. Centralized generating facilities are giving way to smaller, more distributed generation (DG) partially due to the loss of traditional economies of scale. DG encompasses a wide range of prime-mover technologies, such as internal combustion engines, gas turbines, microturbines, photovoltaic, fuel cells, and wind power. These technologies have lower emissions and have the potential to have lower cost, thus negating traditional economies of scale. Others include power support at substations, deferral of transmission/distribution upgrades, and onsite generation. Penetration of distributed generation across the United States has not yet reached significant levels. However, that situation is changing rapidly and requires attention to issues related to high penetration of distributed generation within a given distribution system. Indiscriminant application of individual distributed generators can cause instability problems within the network serviced by these systems (Lasseter and Piagi 2006).

This issue is complex, but the call for extensive development in fast sensors and complex control from a central point provides a potential for greater problems. The fundamental problem with a complex control system is that a failure of a control component or a software error will bring the system down. DG needs to be able to respond to events autonomously, using only local information. For voltage drops, faults, blackouts etc., the generation needs to separate from the grid ("islanding") by using local information. This will require an immediate change in the output power control of the micro-generators as they change from a dispatched power mode to a particular frequency controlled by the islanded section of network, along with load following.

A better way to mitigate these instabilities and capture the full potential of DG is to take a systems approach, which views generation and associated loads as a subsystem or a "microgrid." From a grid perspective, the microgrid concept is attractive because it recognizes the reality that the nation's distribution system is extensive, aging, and will change only very slowly. The microgrid concept further enables high penetration of DG without a redesign or reengineering of the distribution system itself. In this paradigm, the underpinning architecture and its attributes are the defining features that differentiate such systems from more centralized control and dispatch (Figure 3-16).

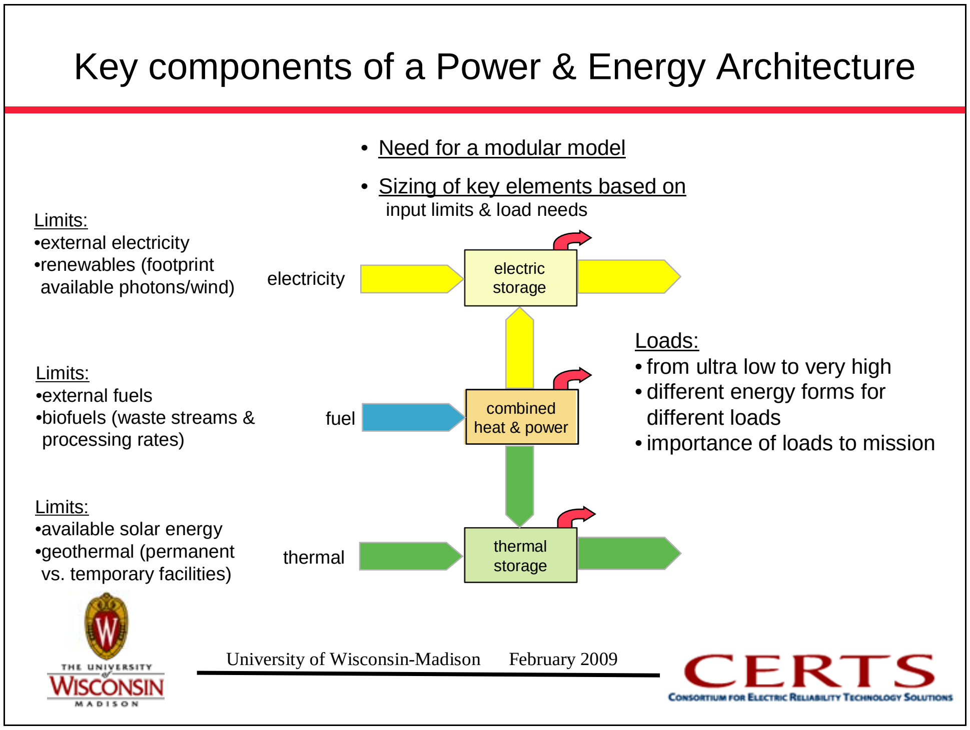

Figure 3-16. Key components of power and energy architecture (Dr. Lasseter).

The following are power and energy architecture features and capabilities:

- full spectrum of applications, from whole campus to forward operating bases
- loads from ultra-low (residential) to very high (maintenance and industrial)
- creation of adaptable and modular building blocks for both thermal and electrical architectures
- optimization of onsite renewables
- thermal energy management is a key issue through combined heat and power
- need for a modular model, with the sizing of key elements based on input limits and load needs.

This approach allows for local control of distributed generation, thereby reducing or eliminating the need for a centralized dispatching and sensing mechanism. During disturbances, the generation and corresponding loads can separate from the distribution system to isolate the microgrid's load from the disturbance (thereby maintaining high level of service) without harming the transmission grid's overall integrity. Intentional islanding of generation and loads has the potential to provide a higher local reliability

than that provided by the power system as a whole. Further, the size of emerging generation technologies permits optimal placement of generators in relation to heat loads, thereby allowing for the combined use of power and waste heat (CHP). Such applications can more than double the overall efficiencies of the systems.

Most current microgrid implementations have the capability to combine loads with sources, allow for intentional islanding, and try to use the available waste heat. These solutions still rely on complex communication and control, are dependent on key components, and require extensive site engineering. An alternative technology is that of the “meshed microgrid,” which can provide these features without the complex control systems requiring detailed engineering for each application. The heart of the approach is to provide generator-based controls that enable a plug-and-play model without extensive communication or custom engineering-site features. The traditional all-encompassing control and dispatch is now delegated locally to a semi-autonomous interactive system-of-systems. A non-trivial consequence to critical military facilities is a significantly increased level of reliability and power quality.

The meshed microgrid has the following attributes and can be used in buildings, larger campus sites, and forward operating bases.

Features of the meshed microgrid:

- meshed for grid and island operation
- plug and play functionality
- autonomous load tracking
- autonomous load shedding
- autonomous load sharing between units
- no limit to the number of modules.

Value added by the meshed microgrid:

- autonomous self-healing
- seamless integration of renewables
- seamless load shedding
- seamless addition or removal of modules
- high level of reliability (n+1)
- networking reduces fuel needs by 50%.

The typical microgrid has two critical components — the static switch and the microsource. The static switch has the ability to autonomously isolate the microgrid from disturbances such as faults, IEEE 1547 events, or power quality events. After islanding, the reconnection of the microgrid is achieved autonomously after the tripping event is no longer present (Lasseter and Piagi 2006). This synchronization is achieved by using the frequency difference between the islanded microgrid and the utility grid, insuring a transient-free operation without having to match frequency and phase angles at the connection point. Each microsource can seamlessly balance the power on the islanded microgrid by using a power vs frequency droop controller. This frequency droop also ensures that if the microgrid frequency is different from that of the grid, the difference can be used to facilitate utility reconnection. This level of autonomous control requires the use of a peer-to-peer, plug-and-play operation model for each component of the microgrid. The peer-to-peer concept ensures that there are no component outages, such as a master controller or central storage unit, that are critical for operation of the microgrid. This implies that the microgrid can continue operating with loss of any component or generator, provided a suitable replacement source is at hand within the microgrid's domain of local control.

The area of major difference from utility generation is the possibility that an inverter-based DG cannot provide the instantaneous power needs, due to lack of a large rotor. In isolated operation, load-tracking problems arise since micro-turbines and fuel cells have slow responses to control signals and are inertialess. A system, with clusters of microsources designed to operate in an island mode, requires some form of storage to ensure initial energy balance. The necessary storage can come in several forms: batteries or super-capacitors on the DC bus for each micro source, and direct connection of AC storage devices (AC batteries, flywheels, etc., including inverters). As an example, the Consortium for Electrical Reliability Technology Solutions (CERTS) microgrid uses DC storage on each source's DC bus to ensure highest levels of reliability. In this situation one additional source (N+1) can provide a complementary functionality for the loss of another component. This is not the case if there is a single AC storage device for the microgrid.

A summary of the meshed microgrid electrical system attributes:

- Each DER unit is a voltage source.
- Peer-to-peer modeling is accomplished by using scalable components.
- Multi-unit stability is insured through voltage vs reactive power control.
- Communication between components is through *frequency*.
  - DER output control uses power vs *frequency* drop.
  - Intelligent load shedding on low *frequency*.
  - Automatic re-synchronizing, by using *frequency* differences between the island and utility network.

Some microgrid constraints:

- Microsource either operates at its *optimal efficiency* or is off.
- Operates when thermal and/or electrical storage is below its threshold energy level.
- Storage is sized to minimize the operation of the microsource as related to the *available renewables* and their attributes.

3.5.4 Summary of basic building blocks for community systems

The four basic building blocks for community system electrical and thermal advancements are listed in Figure 3-17.

Modular Architecture Issues

Electrical
- integration and control of storage and pv in the hybrid energy module
- load control & building electrical infrastructure issues

CHP
- efficient use of electrical and thermal sources
- serving different thermal loads (heating and cooling)
- influence of electrical and thermal storage

Biofuels
- feasible on-site biofuels/gas
- available energy relative to waste streams & process rates
- modular issues

Thermal
- heating and cooling issues
- storage and modular architecture issues
- integration of passive solar, geothermal and CHP

Figure 3-17. Modular architecture issues (Dr. Lasseter).

Electrical storage needs to be resolved as how to best integrate and control PV electricity and its storage in a hybrid energy module. Also, load control and building electrical infrastructure is an important issue. Combined heat and power captures the heat energy of electrical generation. The captured heat is used to generate cooling, heating and/or dehumidification. Locating the onsite generation source near the heating and cooling load areas further enhances the energy efficiency of combined heat and power.

Biofuel generators and waste conversion generators are recognized sources for combined heat and power opportunities at both forward deployed bases and installations. Biofuel developments including extracting energy generating oil from algae, fermentation energy generation and biofuels refinery are options for further study.

Combined heat and power generation is known to meet energy load requirements with as much as 75% less fuel to meet mission goals. The increased energy conversion efficiencies also contribute to greatly reduced carbon footprint and can provide further benefits for installations. Cogeneration power plants are enjoying a surge of interest in Germany due to the improvement of dynamic pressure modeling and simulation software that allows expert users to understand the complex relationship of pipe sizing and pressure needed to distribute cooling and heating to multiple locations from a single, energy-efficient source. Considerable modeling capability improvements will be needed to allow this highly effective energy generation and distribution method to be used on installations and campuses, which are ideal candidates for receiving the benefits of centralized cogeneration. When coupled, the efficiencies of microgrids and combined heat and power could dramatically reduce fuels requirements to fully satisfy mission objectives.

When renewable energy sources and thermal storage are added to the microgrid, along with combined heat and power, it is possible to reasonably project achieving NZE goals for installations and forward deployed bases within established timelines. However, existing models need to be tested using fully funded research activities to verify field condition application. The possibility of exploring “tri-generation” systems that combine cogeneration with absorption chillers, and investigating absorption chillers in the service of thermal storage systems were also discussed. Also, development of smart appliances that can be part of microgrid plug-and-play system would be a great advantage. It was stated that until an entire system of ap-

pliances, modular generators, and microgrid delivery is demonstrated as a whole, research in this area may be “just thrashing around.”

3.6 Physical architecture

3.6.1 Summary

Dramatic reduction in building energy consumption has been realized through a system of design, construction, and operating methods called *Passivhaus* (i.e., passive house*). Originating in German residential construction and expanding into other building types around the world, passive house design, construction, and operating methods been shown to substantially reduce energy load requirements. This construction method can help advance the establishment of NZE communities if planned as a collection of buildings instead of randomly constructed individual units. Figure 3-18 shows the topics presented in this session.

Session IV: **Physical Architecture**

Session Chair: Dr. Thomas Hartranft, ERDC-CERL

General Introduction

Topic 1: Katrin Klingenberg, Executive Director Ecolab and Passive House, USA “US Passive House Project – Net Positive Energy Homes”

Topic 2: Dr. Berthold Kaufmann, Passivhaus Institut, Germany “Passive Houses Worldwide – Basic Conception and Hint for Adaption to Special Climatic Regions”

Topic 3: Georg Zielke, Architektburo Zilke Passivhauser

“What can be done in Passive Housing in the future and in which way of construction?”

Figure 3-18. List of topics in physical architecture (Dr. Thomas Hartranft).

3.6.2 Observations

The passive house concept originated in the German single-family residential construction market, but it has been successfully extended to other types of construction worldwide. The rigorous design, construction, test-

* The German Passivhaus Institute and Passive House Institute U.S. prefer the English spelling “passive house” because it describes a concept, not a brand name.

ing, and operation methods that characterize the passive house concept have been applied to office buildings, schools, athletic facilities, libraries, and multifamily housing.

Katrin Klingenberg presented requirements of successful passive house design, as illustrated in Figure 3-19. She recommended that prospective projects be executed using consultants and contractors who have been specifically trained in passive house design and construction methods.

Figure 3-19. Components of a successful passive house may include a proprietary, purpose-designed upright wall system (Katrin Klingenberg).

Passivhaus designs typically have whole-house energy requirements ranging from approximately 13,000 to 35,000 Btu/square foot/year. By comparison, a well insulated and maintained “control” home in Illinois uses about 55,000 Btu/square foot/year. Overall, the average U.S. Army family housing facility uses approximately 60,000 BTU/square foot/year. So a passive house design may range from about two to five times more energy-efficient than the current average Army family housing unit.

Passive house design is characterized by the following features:

1. superinsulation
2. thermal bridge avoidance in design and construction
3. passive solar design techniques, including daylighting and use of advanced conservation technologies such as triple-pane glazing when required by the climate

4. airtight envelope design, construction, and verification
5. ventilation systems with greater than 75% (measured and verified, HVI rating minus 12%) heat-recovery efficiency, and motor efficiency of 0.7 W/cfm
6. minimized mechanical systems.

Because passive house technology was first developed in Germany, the original concept was tailored to northern temperate climates. Since then, some implementations have been developed for Mediterranean and other humid climates. To fully exploit the energy-reduction benefits of passive house design, however, research is needed for applications in all varieties of climate.

Passive house was pioneered in the northern regions of North America during the 1970s, but also in southern areas such as Arkansas (where the first superinsulation project is said to have been completed in the 1960s). German practitioners have defined clear passive house performance goals and have optimized the technologies based on current climate change consensus and the need to reduce greenhouse gas emissions by a factor of 10. The basic physics principles applied in German passive houses are the same as those in the United States. However, research and testing needs to be extended to include dwellings in hot climates, both arid and humid, because at this point not much progress has been made in those regions.

Extensive design, construction, and operations training will be necessary to achieve the considerable cumulative benefits of the passive house concept. The Army is in a position to standardize and rapidly deploy established passive house technology through a combination of integrated modeling techniques that accelerate learning with design and construction simulation methods. At the same time, passive house methods can be applied to renovation projects. Although renovation projects cannot be expected to achieve the same savings as a new passive house, they can still achieve dramatic energy consumption reductions as compared with aging or obsolete building construction.

Blower door tests and other commissioning activities are needed in order to confirm the required airtightness standards have been achieved. Infrared photography has been used to verify ongoing performance as a part of operation validation.

3.7 Energy conservation

3.7.1 Summary

Buildings either constructed or renovated in future years will have to achieve significant savings in consumption of fossil fuels. Factors driving this will include supply and demand, cost, and government mandates. The savings will need to occur across energy consumption needs including heating, cooling and lighting. Because U.S. buildings consume 40% of total energy used, addressing only easy and quick fixes will not achieve the necessary savings. Available technologies and best building and design practices exist now, but holistic energy system solutions and implementations will be required. Figure 3-20 shows each topic presented during the energy conservation session.

Session IV: Energy Conservation

Session Chair – Dr. Alexander Zhivov, ERDC;

"Energy Conservation Technologies for Net Zero Buildings: Load Reducing Technologies"

Topic 1: Scot Duncan, ROI-Engineering; "HVAC system energy consumption reductions and energy efficient design strategies for the heating and cooling of buildings"

Topic 2: Alan Gillan and Valeriy Maisotsenko, Coolerado; "M-Cycle beyond Comfort Cooling“

Topic 3: John Shoner, Oak Ridge National Laboratory; “Heat Pump Optimization”

Topic 4: Gert Brunining, Philips; “Advanced lighting systems”

Figure 3-20. Topics in energy conservation.

3.7.2 Observations

Dr. Zhivov stated that according to EISA (Energy Independence Security Act 2007), new buildings and buildings undergoing major renovations shall be designed so that consumption of fossil fuel energy (generated off-site or onsite) is reduced, compared with such energy consumption by a similar building in fiscal year 2003 (as measured by Commercial Buildings Energy Consumption Survey or Residential Energy Consumption Survey data from the Energy Information Agency).

The percentage reductions per fiscal year specified by EISA 2007 are:

2010........................ 55%
2015........................ 65%
2020....................... 80%
2025....................... 90%
2030.......................100%

The Federal Energy Management Program (FEMP) is drafting a ruling providing interpretation of EISA 2007. Whatever interpretation that will be, Dr. Zhivov said that by 2030 newly constructed buildings and buildings after major renovations shall be NZEB. He post the question, “How we can get from where we are now to NZEB in 21 years?” He mentioned that buildings constructed today are built with the requirement to be 30% more energy efficient, compared to ASHRAE Std. 90.1. However, those buildings will still be there in 21 years and probably be less efficient than they are now (with a current level of maintenance and no re-commissioning). ESPC projects addressing only “low-hanging fruit” (improved efficiency of lighting, electrical, HVAC systems, controls, etc.) will fail to reduce energy consumption at a current rate (not mentioning the rate required by EISA 2007) and will become less economically attractive. The following is suggested by Dr. Zhivov:

- Development of holistic energy systems concepts and applying them through advanced installation-wide energy master planning
- Setting new more stringent energy targets for new construction and SRM projects executed today with future goals in mind
- Executing renovation projects by building clusters with a potential to integrate these clusters into the low energy community/installation.

This approach requires early adoption and application of advanced technologies in new construction and retrofit projects, and a holistic approach and commitment from all stakeholders (planning, financing, PM, design, construction, O&M, building users, owners and managers.)

Figure 3-21 shows that buildings contribute to a large fraction of energy consumption. In the United States alone, buildings consume about 40% of total energy, including 71% of electricity and 54% of natural gas. The U.S. Army alone spends more than $1 billion for building-related energy use.

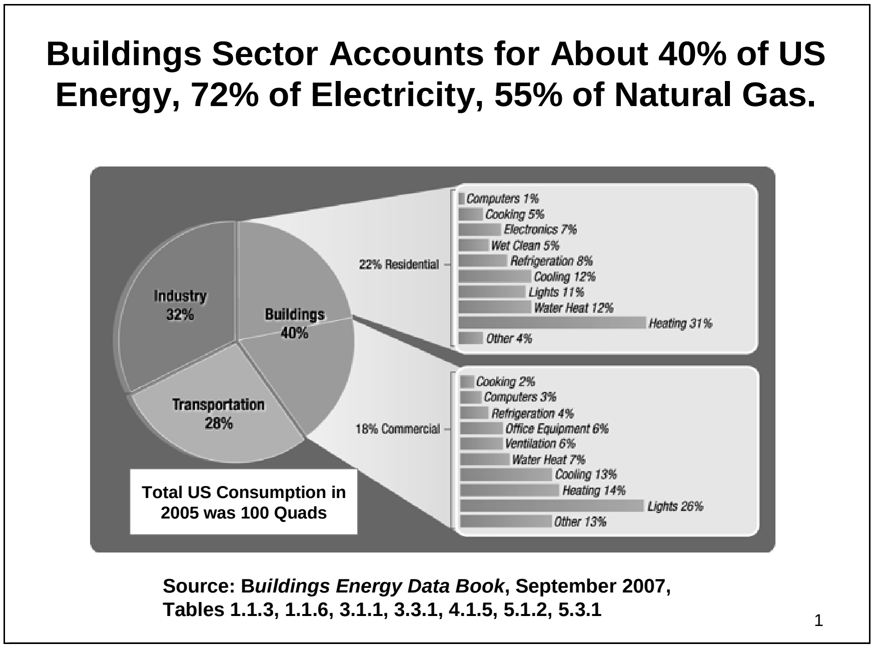

Figure 3-21. Energy consumption of buildings in the United States (Dr. Alexander Zhivov).

Dr. Zhivov presented the boundaries between energy conservation and renewable energy application. A USACE/DOE/ASHRAE study showed that 30–35% energy reduction from the ASHRAE 90.1, 2004 level can be achieved by using currently available technologies and best design and construction practices at no or minimal additional cost (< 2%).

In central Europe, energy reduction in residential buildings up to 90% was achieved in more than 10,000 buildings by using better insulation; airtight building envelope; triple-pane, low-e, energy-efficient windows, energy recovery from exhaust air, advanced lighting and appliances, advanced district systems using cogeneration, at a first-cost increase of < 10%. In the North American climates, energy reduction beyond 35% (up to ~70%) in addition to European technologies, requires advanced cooling and dehumidification technology. The main contributors to increased cost are advanced windows, lighting, and advanced appliances. Between 70% and 100% of fossil fuel reduction will require the use of central systems with integrated renewable sources of energy and thermal and electrical storages.

Reducing energy use in buildings is feasible and economical. Depending upon the energy cost and climate, existing and advanced technologies and design strategies can reduce energy consumption up to 80-90%. German experience shows that with the current energy costs, even residential NZE

buildings are not yet economical. However, NZE communities are feasible with a reasonable payback. They require optimization of the building envelope and systems for each building and building clusters

While low-energy or Passivhaus technologies and design strategies for residential buildings are a common practice in Europe, a holistic approach required to develop NZE building communities with diverse sets of buildings is still in the stage of “art.” Optimizing building loads, building community systems with a consideration of different low- and high-quality energy sources and waste streams, and thermal and electrical storage systems require further studies.

With buildings accounting for 40% of total energy use in the United States, it is clear that significant developments in facility efficiency are necessary to meet NZE goals. Existing regulations, including the 2005 Energy Policy Act, EPACT 2005 and EISA 2007 provide clear mandates for reduced energy use by building facilities, including those of the Army. Existing, proven technologies can be leveraged to meet up to 30% of the energy reductions required by regulation. However, 70–85% net reductions are essential to meet NZE goals by 2030, and will require a host of solutions linked in a systematic manner. The menu of solutions will need to include the following:

- innovative technology research, development and demonstration
- creation of holistic design, construction and operation standards
- improved control systems
- advanced sensors
- commitment to education innovation
- modeling and simulation improvements
- integration of modular systems
- semiconductor controlled LED lighting
- interoperability of software and hardware.

While significant improvement in individual building performance is understood as a necessary design and operational requirement, it will take improved community system performance metering, modeling, control, and operation to achieve the highest-level NZE goals. Planning and implementation for NZE community systems is presently in the conceptual phase of “state of the art.” Moving these NZE community paradigms to the “state of the science” phase will be necessary in order for the Army to

achieve repeatable performance from all of its installations and deployed bases.

Key to reaching a "state of the science" phase will be development of controls that can be easily understood and used by non-engineers. "Poor controls waste more energy than any highly efficient system can save" was a well-turned phrase that summed up a recurring call for efficient operation of HVAC systems. Similarly, effective community systems controls are needed to gain energy efficiency from the next, greatest opportunity for energy conservation – a community systems approach.

3.8 Building envelope and materials sciences

3.8.1 Summary

The building envelope for permanent structures and portable structures offers many crossover-learning opportunities between deployed bases and permanent installations. The importance of airtightness, the use of existing technologies in advanced manners, and the need for modular, repeatable, easily operated energy-efficient technologies are universally needed in both forward positions and in homeland operations (Figure 3-22). The U.S. Army can transition this technology, enabling lessons to be transferred between both types of installation in a mutually beneficial manner.

Session VI: **Building Envelope and Materials Science**

Session Chair: William Rose, Research Architect, University of Illinois "Building Envelopes and Materials"

Topic 1: Steven Tucker, Natick Labs "Materials for Deployed Bases", "Flexible Photovoltaics"

Topic 2: Henri Fennell, Foam Tech "Materials: Foam, Air Tightness, Compliance"

Figure 3-22. Topics in building envelope and materials science.

3.8.2 Observations

Session Chair, Mr. William Rose, began by recognizing the long history of significant contributions the Army Corps of Engineers has made to the building industry. He wanted to be on record as recognizing this workshop as another significant contribution to the overall advancement of the building industry.

Mr. Rose presented building envelope principles as follows:

- good roof, dry foundation
- exterior thermal insulation
- low value to insulation in metal stud assembly
- discontinuities with interior application
- glazed wall percentage kept < 30%
- continuity of insulation, airtightness ensured at details.
- durability primarily a function of rainwater drainage and maintenance
- existing buildings rising in importance
- standards exist to address common vapor protection questions. (ASHRAE 160)
- fund maintenance, operation, repair, and replacement.

Figure 3-23 shows the effect of airtightness on the control and variability of interior environment presented by Mr. Rose. According to this graphic, the more a building leaks, the higher are the costs of operations and maintenance in achieving a particular level of comfort.

Mr. Rose stated that with improving the building envelope for existing buildings, retrofitting is sometimes more costly than building a new building (Figure 3-24). When preservation or cultural appreciation is required, existing buildings are renovated and improved for lower-emissivity surfaces, high quality, and air barriers. In improving existing buildings, one important question to be answered is, “How long should the building last?” The relation of this question to improving existing buildings is shown in Figure 3-25.

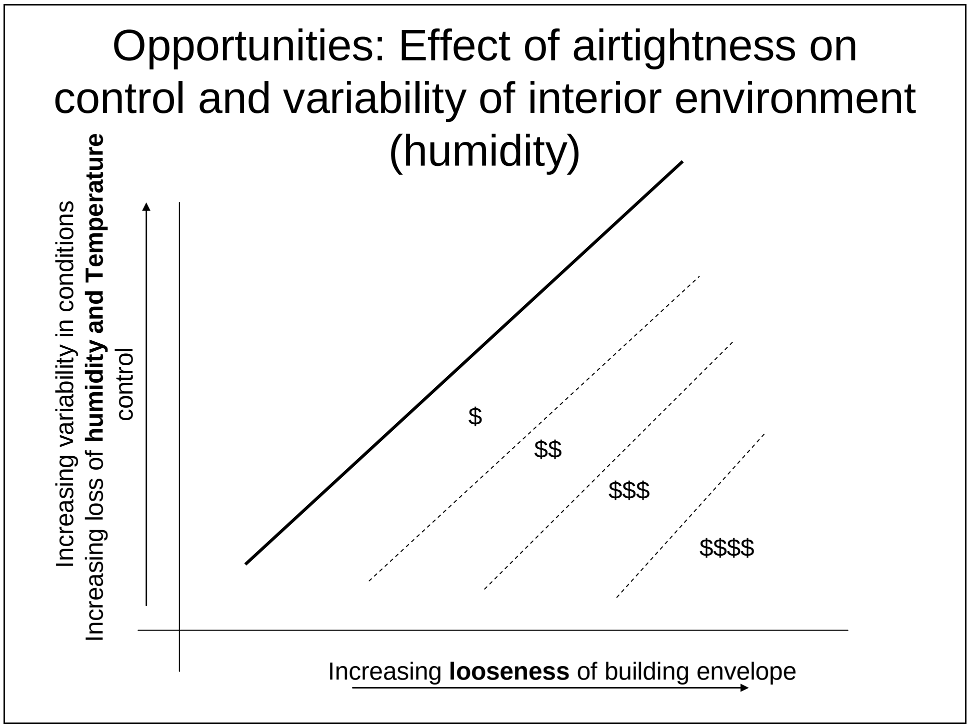

Figure 3-23. Effect of airtightness (William Rose).

Building envelope opportunities--not-so-hot

Dynamic wall
Phase change materials
Double-wall construction
Vacuum panels
Thermal insulation at metal studs
Insulating existing buildings at the interior
Replacement windows
try insulated storms

Figure 3-24. Costly building envelope retrofit technologies (William Rose).

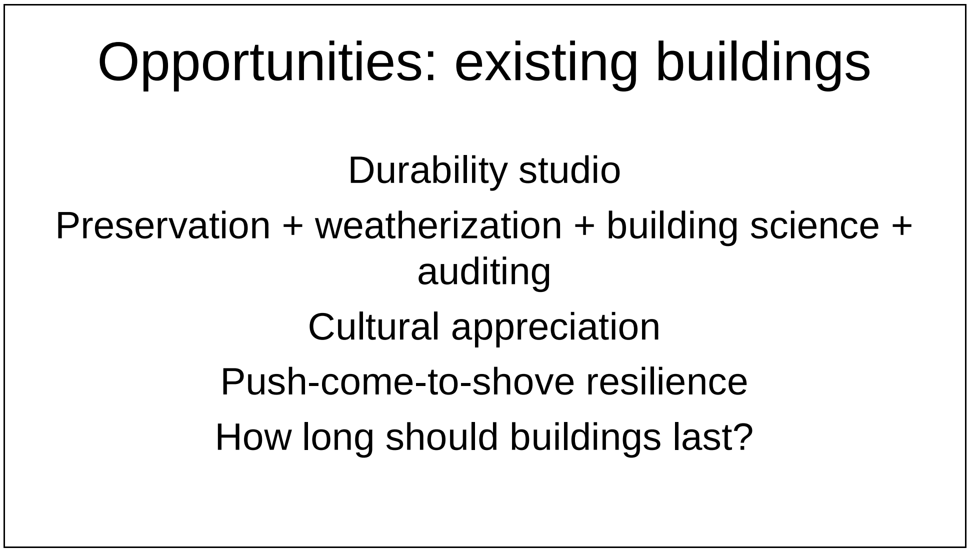

Figure 3-25. Building envelope opportunities for existing buildings (William Rose).

Airtightness was stated as being a highly important factor in ensuring improved energy performance in permanent and temporary structures. In addition to calling for measures to improve airtightness, the following was also advocated:

- advanced metering
- transparency of utility data
- development of wireless, mobile sensors
- Web-based reporting capabilities
- tracer gas improvements
- simultaneous diagnostic and leak tracking
- airtightness specifications
- energy "dashboards" in standardized controls
- performance-based contracting
- advanced three-dimensional modeling capabilities
- creation of a building envelope full-scale test laboratory to build mock-ups, create blower door tests, and develop equipment such as thermography imaging units.

Advanced foam insulation capabilities have provided significant energy conservation capabilities and promise to deliver more, with properly funded applied research. Having significantly addressed the negative environmental impacts of CFC blowing agents, foam insulation is poised to provide both insulating capabilities and airtightness benefits, due to the ability of the wet-blown polyurethane material to expand into any almost any cavity. Expanding foam can provide a large increase in thermal per-

formance by providing both insulating value and measurable airtightness of building envelope. High-level performance, such as insulating 4% of a building envelope resulting in 40% reduction in energy consumption, suggests that well-defined, standardized foam insulation programs may contribute to reduced energy consumption in existing buildings. When also considering the vapor retarding and fire prevention capabilities, this technology can be explored in great detail on many levels.

Even with higher levels of airtightness achievable with expanding foam technologies, there is a need for development of advanced air leakage testing such as fog testing, improved monitoring systems, and pattern analysis capabilities.

A field-ready, renewable energy technology is the application of amorphous, thin film photoelectric to the surface of shade structures and battery recharging mats. A small, wall-less PV shade tent can generate 1 kW of power while a medium-sized shade tent can generate 2 kW. The tents can power portable 1 kW batteries with integrated DC to AC conversion capabilities. The rollable, foldable fabrics can be walked on and can be combined in an integrated modular daisy-chain manner. Smaller fly tents can generate 200 W and 750 W individually or again can be interconnected in larger configurations. Rollable PV mats can recharge AA batteries in 4 hours of full sun.

No special tools or special engineering knowledge is needed to erect and operate these renewable energy PV technologies that can help reduce logistical fuel tails.

The biggest barriers to meeting NZE for community systems includes improper metering, lack of publicly available utility data, and the lack of a case study database to allow ongoing modeling and assessment of existing buildings, as shown in Figure 3-26.

Barriers

Metering, reporting, auditing, analysis, summary
Projections (models) cannot indicate variance
Owners resent publication of utility data
Tennessee example: utility data is public
Reluctance to do program evaluation
Contracting for high performance
Resistance to **airtightness** standards
Design-bid-build delivery
Complaints of unavailable equipment and expertise
Case studies in peer-review literature
Owners' reluctance
Control by reporting parties
Few venues, low standing

Figure 3-26. Technology barriers for NZE building envelopes (William Rose).

Mr. Rose concluded his presentation by emphasizing paths forward in three areas:

1. Improve energy reporting by doing the following:
   - meter everything
   - make data available for research purposes
   - determine variability of energy use
   - conduct program evaluation
   - avoid reports like GAO 1980
   - develop energy dashboards
   - gather wireless data transmission from sensors
   - provide energy-conserving opportunities by Web
   - conduct pre-post, retrofit studies directed from afar
   - collect and analyze retrofit assist studies
   - improve case study reporting
   - adopt "no excuses" standard.

2. Performance contracting will:
   - support specifications for performance, including airtightness specification
   - ensure the delivery vehicle can deliver performance
   - design-build, probably
   - design-bid-build, unlikely

- provide oversight, QA, and commissioning, to ensure compliance; and
- find paths for correcting noncompliance.

3. Tracer gas improvements have these characteristics:
   - CO_2, SF6, He, PFT are common, but all have limitations
   - recommend development of microtracers
   - snapshot usually with one mode of operation at one wind speed
   - simultaneous diagnostics and leak tracing
   - hole performance may be distorted by pressure
   - conducted over time (various modes of operation at various wind speeds)
   - does not aid thermography
   - captures correct hole performance; and
   - gases may be troublesome.

3.9 Tools and systems analysis methodologies

3.9.1 Summary

Analysis tools for individual building energy performance need to be supplemented with additional modeling analysis capabilities and the ability to tie all model data together in a manner that allows meaningful interpretation of community systems performance, not just single building performance. Figure 3-27 shows each topic presented during the session on Tools and Systems Analysis Methodologies.

Session VII: **Tools & Systems Analysis Methodologies**

Session Chair: Dr. Jacob Brouwer: Ntl Fuel Cell Research Ctr. – UC, Irvine "Engineering Analysis of Fuel Cell and Integrated Hybrid Technologies for Support of the NZE Concept"

Topic 1: Ron Judkoff, National Renewable Energy Laboratory "Modeling, Simulation and Measurement of Building Energy Performance"

Topic 2: James Meacham, CTG Energetics "Zero Energy Building Technologies"

Topic 3: Karen Fleckner, Nu Element "Renewable Fuel Cell Systems"

Topic 4: Lucio Soibelman, Carnegie Mellon University "Automatic Disaggregation of Total Electrical Load from Noninstrusive Appliance Load Monitoring"

Figure 3-27. List of topics in Tools and Systems Analysis Methodologies.

Integration of load profile engineering across all building types and all types of energy fuel sources is necessary to fully understand the day-to-day engineering capabilities necessary to achieve and maintain NZE requirements. Existing Department of Energy and university focus on individual appliance and residential NZE capabilities needs to be expanded to community systems. In fully integrated energy communities, excess renewable energy from buildings can be channeled into transportation energy sources such as hydrogen fuel cells.

3.9.2 Observations

Dr. Jacob Brouwer opened his topic of Tools and Systems Analysis with near NZE thoughts in four different ways:

1. Do as much energy saving, energy efficiency as possible.
2. Use as much renewable power as possible (challenges: intermittency, non-coincidence, remoteness, cost, integration with demands).
3. Complement with dispatchable resources: DG, CHP, biomass, hydro.
4. Handle instantaneous power and power quality (PQ) with smart communications and control.

Dr. Brouwer put forward the concept of communities as *Power Parks* (see Figure 3-29) that can quickly implement near-term steps to make significant progress toward achieving NZE goals. These include the following:

- Implement as many energy conservation measures as possible.
- Use as much renewable energy as possible.
- Develop complementary, dispatchable energy technology.
- Create smart energy communication technology, power quality monitoring, and controls that can instantaneously provide valid data for community system power load profile engineering.

Figure 3-28 illustrates the importance of integration. In a housing/residential example, one sees different requirements and activities (increased heat load in the winter and increased cooling load in the summer). Therefore, it is important to integrate the different aspects in terms of load profile engineering.

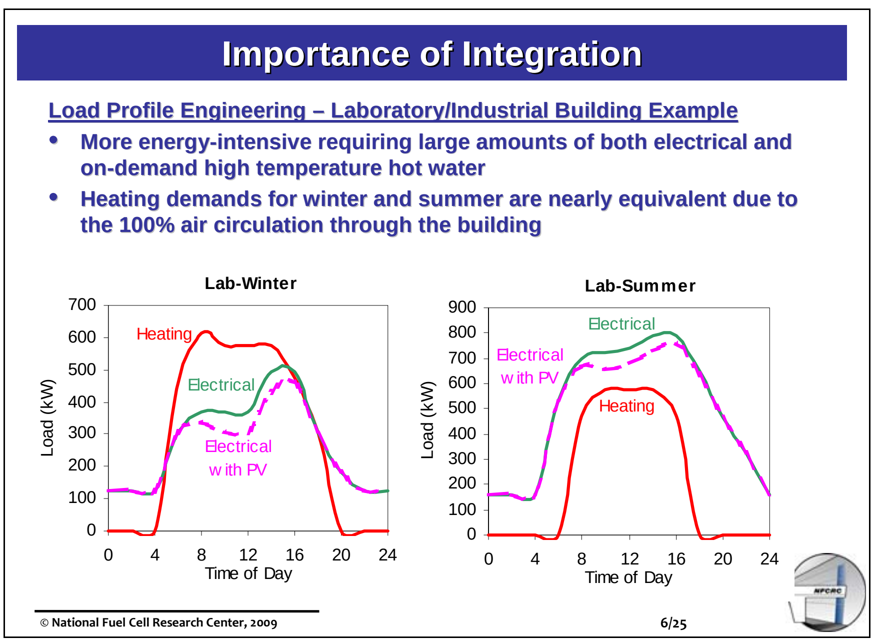

Figure 3-28. Importance of integration (Dr. Brouwer).

System integration enables the efficient coupling of energy production prime movers (steam, electrical, solar, wind, bio, etc.) into a coherent power source capable of supplementing more traditional utility structures. Such diversity lends itself directly to the "Power Park" concept with all its attendant savings of energy and GHG emissions (see Figure 3-29).

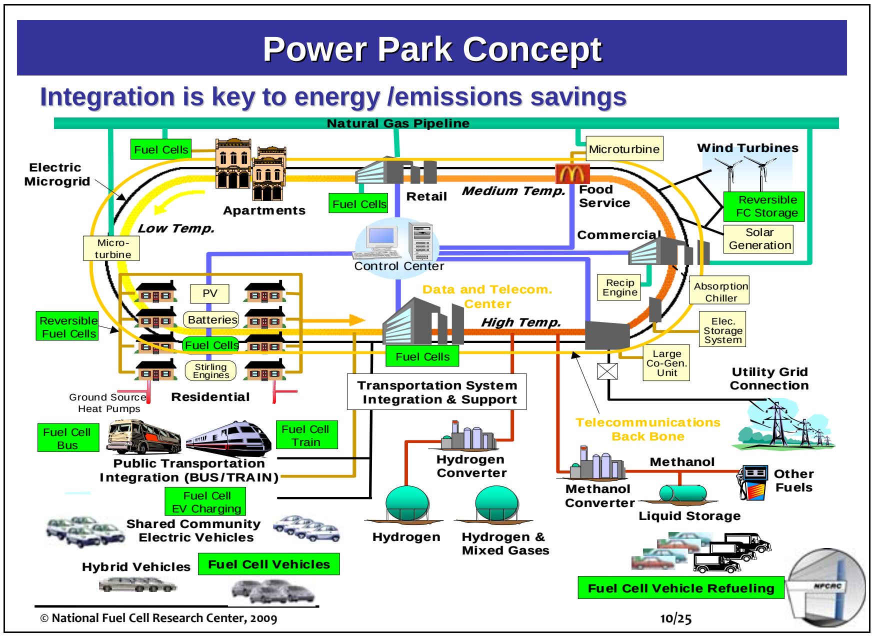

Figure 3-29. Power park concept (Dr. Brouwer).

Furthermore, the non-centralized locations of key power elements (i.e., solar carports) makes for efficient refueling of non-carbon based transportation systems like dedicated electric vehicles and mass transit. Figure 3-30 shows a plug-in hybrid fuel cell vehicle (PHFCV) which has the advantages of meeting long-range driving demands, fast refueling, and a small, cost-effective fuel cell (FC).

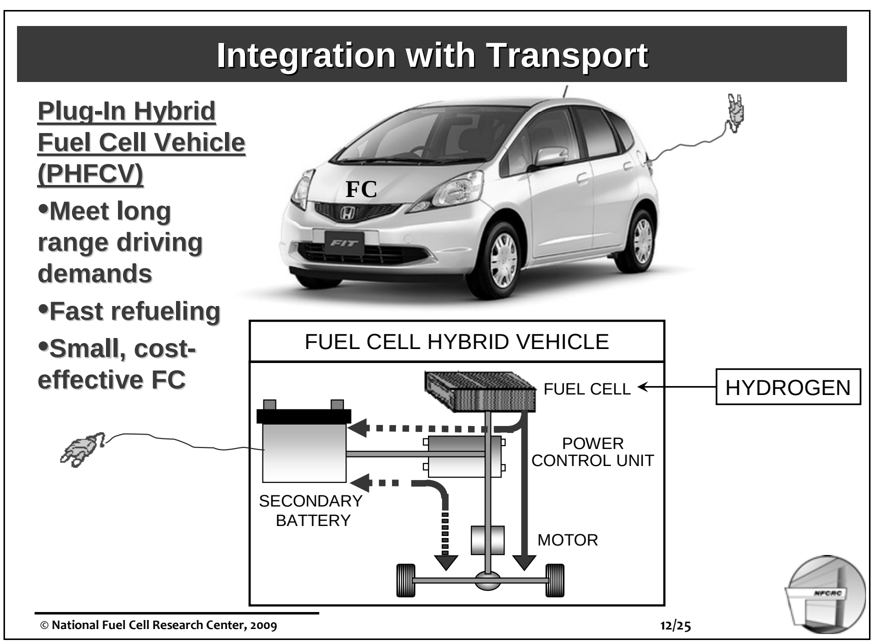

Figure 3-30. Integration with transport (Dr. Brouwer).

Node systems can allow better management of Power Park load profile engineering, as shown in Figure 3-31. Node systems that allow instantaneous balancing if any one node under performs or fails can be seen as a large-scale application of microgrid systems and may allow research exchange between projects focused on forward deployed bases and installations.

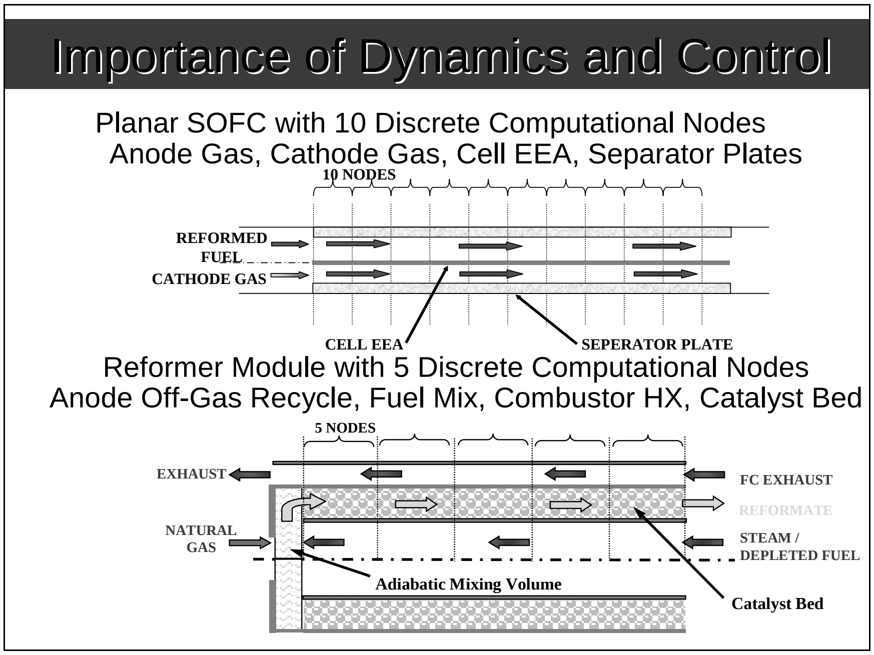

Figure 3-31. Node system in importance of dynamics and control (Dr. Brouwer).

Key to the system integration is the fundamental element of *dynamic systems control*. These well-designed systems sense and integrate, in real time, the power dispatch requirements necessary to achieve a known-demand power level within a constantly changing environment. The following is a summary of Dr. Brouwer's presentation on dynamic modeling tools (MATLAB/Simulink), a program chosen for the following reasons:

- user-friendly, widely available/used, ideal for controls development
- variability of energy sources makes energy storage a requirement to supply the majority of power demand in residential stand-alone photovoltaic systems
- separate energy from gas and electricity can be efficiently modeled, using combined heat and power simulations.

Integration of HFC-charging technology into comprehensive planning can allow renewable energy for transportation to be incorporated into NZE community systems. Initial results from studies of shared, renewable en-

ergy vehicles and modeling of buildings that power the vehicles indicate opportunities for further research. NASA studies of fuel cell technologies for transportation did not consider linking into a renewable energy community system grid. Filling this gap in engineering science may be a key element in achieving comprehensive fulfillment of NZE community systems.

Modeling capabilities could be part of a comprehensive Facilities Warfighting Simulation Lab that allows multiple modeling programs to be integrated into a single NZE community system "gaming" environment to accelerate development of the right technology in the most effective sequence to meet phased objectives moving toward final goals established for the year 2030. Development of hydrogen fuel cells through onsite electrolysis could be further explored in an NZE community systems simulation lab. A comprehensive Facilities Warfighting Simulation Lab may also be used as an innovative means of accelerating the education needed to achieve NZE community systems.

Expansion of existing load balance engineering of commercial buildings in place at the University of California, Irvine, can lead to deployment of dynamic modeling and precision controls of fuel cell energy for both facilities and transportation. Existing demonstrations can be expanded in increasingly larger Power Park configurations at University of California campuses in Irvine, Santa Barbara, and Merced, where small-scale testing has commenced on a minor level.

The significant drain that fluctuating community loads place on peak load demands may be better managed in load balance engineering if all facilities are included in a full community system model.

3.9.3 Zero Energy Building: Smoke? Mirrors? or What? (Ron Judkoff, Principal Program Manager, Buildings R&D, NREL)

Mr. Ron Judkoff demonstrated how to achieve ZEB (zero energy building) by addressing eight different subjects, as shown in Figure 3-32. He stressed the building envelope and orientation to reduce/meet cooling and heating loads. Daytime lighting and climatic considerations are important factors in designing a building. He stressed the site-specific renewable guidelines within footprint, onsite, and offsite, considering that only a small amount of energy is produced from most renewable energy technologies. It should be noted that Figure 3-32 refers only to buildings. Re-

search needs to be expanded to include all types of facilities in a single community model, capable of incorporating data from multiple-energy source types and multiple-facility types in addition to transportation energy loads.

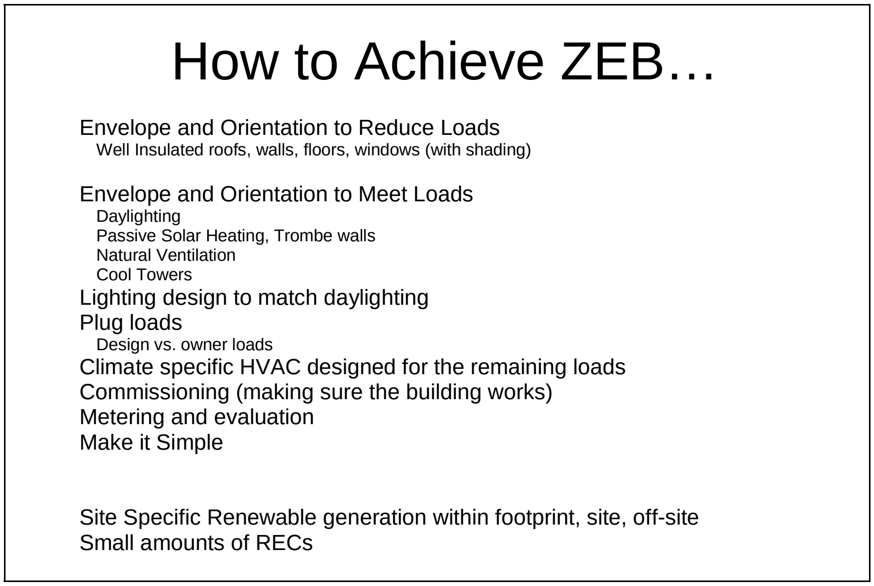

Figure 3-32. How to achieve ZEB (Ron Judkoff).

Figure 3-33 emphasizes the importance of R&D in improving simulation models. Improved modeling of ventilation conditions, moisture conditions and ground conditions can add to better understanding of achieving NZE buildings, but until modeling of community systems is capable on a consistent and reliable manner, ultimate NZE goals may be elusive. Better calibration of issues such as energy storage and reliable utility data can contribute to research models and to accurate real time models that can help align consumer behavior with NZE goals.

Path Forward: R&D Needs:
Improve Simulation Models

- Complex & Innovative Systems & Controls
  - Evaporative Cooling, Desiccant Systems,Innovative Storage Systems, Natural Ventilation Integration, Heat Pump Systems
- Better Moisture Models
- Better Ground Coupling Models
- Optimization for Existing Buildings
  - Calibration Methods
- Dedicated Empirical Validation Facilities
- Multi-Building/Community Models & Optimization

Figure 3-33. R&D requirements for a path forward (Ron Judkoff).

Occupant behavior is critical to achieving NZE goals. Human behavior engineering models can attempt to be incorporated into a Facilities Simulation Lab. However, the integration of advanced appliance meters and controls with human behavior engineering models that are then coupled within single facility models is extremely complex. Further complexity arises when these models are then tied to community system analyses that further include energy source models and controls. This level of complexity will define new frontiers in first-principle systems integration research.

4 Summary, Conclusions, and Recommendations

4.1 Summary

The ERDC-CERL Energy Branch planned, coordinated, and led an Army NZE Installation and Deployable Bases Workshop 3–4 February 2009 at the Crowne Plaza Hotel, Colorado Springs, CO. The workshop hosted approximately 80 participants from major research universities, Department of Energy national laboratories, the Army and Navy facility command and management stakeholders, the Office of the Secretary of Defense, industry experts, Public Works and Government Services Canada (PWGSC), the International Energy Agency, and state governments.

Workshop participants made compelling arguments that reducing energy consumption is in the best geopolitical interests of all energy users, whether military or private sector. This point is especially true for the areas of forward-operating bases and warfighter support. Ultimately, Army planning and policy development must consider all global generation aspects and reconsider energy conservation in the broadest context. In this new paradigm, so-called “secondary” sources of energy will be placed on a competitive footing with traditional prime power sources of electrical and steam generation. The conservation side of the equation requires one to begin seriously tracking the flow of all free energy and its storage within the “installation envelope” in order to approach realistic thermodynamic constraints for all rejected energy. Achieving these goals will be challenging and will require significant research, application, and policy development investments.

The energy generation, storage, building science architecture, and control strategies described during this workshop have a direct application in the NZE community solution. The use of these tools in the large-scale solution requires the development of a properly designed and executed suite of ultra-low-energy systems that would enable adaptable, modular, and scalable electrical power and thermal energy architecture that can accommodate a full spectrum of local mission needs — whether a small facility complex, an installation subsection, a fixed military installation, or forward-deployed base. Accommodating this diversity in an ultra-low-energy

environment will require careful integration of building automation, utility management and control systems, and power delivery systems with the capability to offer integration of onsite power, energy storage, and energy conservation. The controlling features embodied in the integrated suite of tools, systems analyses and methodologies, must not only optimize design but also day-to-day and hour-by-hour operation. In addition, there is the necessity for clarification of the relevant benefits and optimized tradeoffs for incremental 2009 – 2030 investments between energy demand reductions, storage, onsite distributed energy sources, and efficient modeling and analysis tools. In due course, all these concepts require real world implementation and validation through well designed field demonstrations.

The seven main technology categories addressed by the NZE workshop were established with the intention of defining significant areas of study. The categories were also intended to be integration anchors between rationally identified areas of traditional processes. The significant overlap of data and findings presented in each category and the consistent call for similar processes and research through all sessions indicates successful identification of integration points.

4.2 Conclusions

The key conclusion emerging from the workshop is that NZE goals will be most readily achieved if addressed as a community system instead of as a building-by-building approach.

A second significant conclusion is that a community systems approach calls for technical development of similar items. In turn, overarching technical developments can promote advances in each of the seven technology thrust categories. The five high-level technical research and development requirements are:

1. improved community system modeling capabilities that can process data from many software programs
2. improved metering and sensor technologies that display real-time data to individual users and engineers in a manner that will show if community systems are operating in alignment within the parameters of the established model
3. improved controls that allow community systems to be adjusted in accordance with the established model

4. integrated NZE community system standards housed in a Web-based knowledge repository to allow innovative collaboration that enables rapid development and distribution of repeatable actions
5. facilities simulation laboratories that enable testing of NZE community systems.

4.3 Recommendations

4.3.1 Systems integration

One of the current major challenges revealed through the workshop is that the specific system dynamics for the installation-wide "system of systems" are currently unknown or poorly understood. A realistic goal therefore, is to develop a concept and a suite of tools for NZE community systems. Workshop results clearly indicate that there are many different systems for individual technologies and practices to get to NZE or near-NZE for installations or communities. However, the systems are for specific things (buildings, renewables, grid, etc.) and one needs to be able to identify and control interactions between the various systems, new construction versus retrofit opportunities, the option for central plants and heat recovery, and solutions in time domains ranging from fractions of seconds to hours/days, etc. Thus, seamless integration of onsite distributed energy sources is recommended.

4.3.2 Holistic design and implementation

A holistic approach towards the development of NZE communities, comprised of diverse sets of buildings, is recommended. While significant improvement in individual building performance is understood as a necessary design and operational requirement, it will take improved community system performance metering, modeling, control, and operation to achieve the highest level NZE goals. NZE community systems planning and implementation is presently in the conceptual phase of "state of the art." Onsite distributed energy resources (DERs), efficient use of thermal waste heat from DERs, storage to 'level out' renewables' intermittencies, and blended electrical and thermal architecture will significantly reduce building demand. However, power partnerships with civilian communities still require further studies. Thus, moving these NZE community paradigms to the "state of the science" phase will be necessary in order for the Army to achieve repeatable performance from all installations and deployed bases.

4.3.3 Standards documentation

To achieve the modeling, metering, sensor and controls advancements, technological standards need to be established. For the cases where commercial industry organizations are finding it difficult to act with consensus, standards creation by the U.S. Army and its research teams can help implement workable standards required to achieve the Army's unique goals. Establishing workable standards within the framework of commercial standards will break through proprietary log jams and ensure efficient utilization throughout the industry.

Creating a Web-based knowledge repository of existing standards that impact development of NZE community systems will greatly accelerate mission success. Being able to extract the standards that most directly apply to U.S. Army conditions so that they can be reviewed, adjusted, and distributed for implementation will demonstrate a breakthrough in both knowledge management technology and advanced standards development. Regulations and legislation could also be included in the knowledge repository if appropriate funding is available.

4.3.4 Simulation modeling

Using the Web-based knowledge repository of standards, it will be possible to establish criteria for all appropriate analysis and data to be incorporated into an NZE community systems model. The model can be used to test and validate design assumptions. It can analyze construction costs, methods, and sequencing. It can also be used for measuring ongoing operation effectiveness.

While there are many advanced modeling capabilities in specific areas of building science, no community systems model exists to demonstrate the integrated impact of all issues that impact NZE. The technology exists to enable an NZE community systems model, but the articulated will and financial resources have not been brought together in a way that establishes a beachhead of success in this area. Executing these ideas will require vision and will at the highest levels of government.

4.3.5 Metering, sensors, and controls

In order to ensure proper operation of blended energy generation (both thermal and electrical) and appropriate operation of highly effective appli-

ances and building operations, it will require advanced metering, sensing, and controls. The careful installation and network articulation of these systems is a nontrivial matter requiring both initial design skill and care in secondary installation execution and operation. To achieve these ends will require a careful hand-in-glove approach to the design and engineering of controls that can be easily understood and used by non-engineers. “Poor controls waste more energy than any highly efficient system can save” was a well turned phrase that summed up a recurring call for efficient operation of many types of control systems.

4.3.6 NZE conferences

Periodic NZE conferences are recommended to address each of two constituencies with different information needs. One type of conference would continue gathering high-level information about emerging developments and opportunities that can be rapidly deployed. The other type of conference would provide education and training for Army NZE community system stakeholders, who could benefit from reduced energy use.

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14. ABSTRACT

The United States faces profound security and economic challenges directly related to the growing constraints on established global energy resources. U.S. Army energy demand is projected to outgrow affordable supplies even after accounting for the impact of anticipated energy efficiency and management innovations. In order to prevent unacceptable energy scarcities and unaffordable costs, the Army needs a paradigm-changing approach that combines the concept of net zero energy (NZE) usage with a comprehensive and integrated architecture encompassing energy generation, delivery, storage, and demand management. The purpose of that change would be to facilitate development of a suite of ultra-low-energy solutions that would approach NZE usage by enabling real-time optimization of power supply, demand, and storage management for Army facilities, emplacements, or fixed installations of any size.

In support of these objectives, the U.S. Army Engineer Research and Development Center – Construction Engineering Research Laboratory (ERDC-CERL) convened a workshop to provide a forum for leading research scientists and engineers to help the Army define the technology requirements for implementing this vision. This report summarizes the proceedings of the workshop and defines a way forward for an applied research program capable of producing ultra-low-energy solutions for the widest variety of military facilities and emplacements.

15. SUBJECT TERMS
Net Zero Energy (NZE), military installations, conservation, efficiency, microgrids, Passivhaus (passive house), renewables, sustainability

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